CONFIDENTIAL

CCN ~~3~~ ~~4~~ 7E

CLASSIFICATION CHANGE

TO - UNCLASSIFIED ~~CONFIDENTIAL~~

By authority of T.D. No. 74-235

Changed by L. Shirley Date 3-22-74

X 63-82480

Code 5A

(NASA TMX 50967)

A FEASIBLE APPROACH FOR

AN EARLY MANNED LUNAR LANDING.

PART II:

DETAILED REPORT OF AD HOC TASK GROUP (U)

Restriction/Classification Cancelled

JUNE 16, 1961

HEADQUARTERS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, Washington D.C.

auth. next p.

~~EXCLUDED FROM THE GDS~~

CONFIDENTIAL

CONFIDENTIAL

AD HOC TASK GROUP

et al June 16, 1961 O reg

William A. Fleming - Chairman, Hq.
Addison M. Rothrock - Deputy Chairman, Hq.
Albert J. Kelley - Hq.
Berg Paraghamian - Hq.
Walter W. Haase - Hq.

Spacecraft
John H. Disher - Hq.
Merle G. Waugh - Hq.
Kenneth Kleinknecht - STG
Alan B. Kehlet - STG

Launch Vehicles
Eldon W. Hall - Hq.
Melvyn Savage - Hq.
Heinz H. Koelle - MSFC
William L. Lovejoy - Hq.
Norman Rafel - Hq.
Alfred M. Nelson - Hq.

Facilities
Samuel Snyder - Hq.
Robert D. Briskman - Hq.
Secrest L. Berry - Hq.

Life Sciences
James P. Nolan, Jr. - Hq.
A. H. Schwichtenberg - Lovelace Foundation

Advanced Technology
Ernest O. Pearson, Jr. - Hq.

Space Sciences
William Shipley - JPL
Robert Fellows - Hq.

The efforts of the Ad Hoc Task Group were supplemented very significantly by major contributions in each technical area from a large number of other staff members at the various NASA Centers and at NASA Headquarters. Although these added participants are too numerous to mention individually, their contributions are a vital part of the study results.

TABLE OF CONTENTS

INTRODUCTION *

PURPOSE AND STUDY APPROACH

This report, in two parts, presents a program development plan for attempting a first manned lunar landing in 1967. The two parts consist of a Summary Report and a Detailed Report representing the coordinated output of the Ad Hoc Task Group assigned to the study. The study was started in response to the request for such a study by the Associate Administrator in his memorandum of May 2, 1961 establishing the Ad Hoc Task Group.

The purpose of the study was to take a first cut at the tasks associated with the design, development and construction of the equipment and facilities as well as the development of the crews, and to show the time phasing of these tasks. Included are the space sciences, life science and advanced technology tasks whose data and results are needed for designing and developing the systems required in carrying out the mission.

The plan presented in the two reports does not presume to be a firm plan. Its basic purpose is, by choosing one feasible method, to size up the scope, schedule and cost of the job, discover the main problems, pacing items and major decisions and provide a threshold from which a firm and detailed project development plan can be jointly formulated by the various elements of NASA.

Parallel to this study a second NASA study has been carried out to examine other ways of accomplishing the manned lunar mission than the direct ascent method with chemical boosters. (A Survey of Various Vehicle Systems for the Manned Lunar Landing Mission, NASA, Lundin Committee Report, June 10, 1961).

---

* This introduction is included in both the Summary Report and the Detailed Report.

The ultimate method chosen for the mission must still be decided and a firm plan defined. The 1967 target date for the first manned flight to the moon is a radical departure from the NASA Long Range Plan of January 1961. The latter was paced in accordance with a budget growth in space exploration aimed at performing the first flight in the post-1970 period whereas this report indicates how an early mission can be accomplished, and how much it will cost.

The study does not consider the nature of the activities on the lunar surface once the crew lands, nor how long they will stay there before returning to earth. It was believed that this was not of vital concern at this preliminary stage of the planning. However, it must certainly be given serious consideration in any further planning.

The study was directed by the headquarters staff but a number of field center personnel were brought in to participate as members of the task group. The many tasks involved in each phase of the program were defined and interrelated in time and sequence networks. These networks were machine processed by the Sequenced Milestone System, a variation of PERT, to discover slacks and overruns in program time. After several trials, compatible networks were derived which fitted the chosen starting date of July 1, 1961 and the mission target date of August 1967. A total of about 1,800 discreet tasks were included in the ultimate composite networks of the complete program.

GROUND RULES AND GUIDELINES

The following ground rules and guidelines have governed the flexibility of the program development plan. Some were established by the Associate Administrator in his directive of May 2, 1961 initiating the study, others evolved in the early part of the study.

1. Manned lunar landing target date in 1967.

2. Direct ascent without rendezvous was the approach selected early in the study. However, rendezvous was considered to be an essential program in its own right. It was not included in the funding for the manned lunar landing program even though it may serve as a backup method for accomplishing the mission.

3. Intermediate major space missions such as manned circumlunar flight, unmanned soft lunar landing, etc., are desirable at the earliest possible date to aid in the development of the manned lunar landing system and to produce a series of accomplishments between now and 1967.

4. The use of Saturn C-2 for intermediate missions may be evaluated relative to an alternate launch vehicle having a higher thrust first stage and C-2 upper stage components.

5. Parallel development of liquid and solid propulsion leading to a Nova vehicle is to be assumed.

6. Nuclear powered launch vehicles shall not be considered in the first manned lunar landing mission. However, nuclear power generation source may be considered for the spacecraft if it appears feasible within the time limitations of the program schedule.

7. The flight test program is to be laid out with adequate launchings to meet the needs of the program considering the reliabilities involved.

8. Alternate approaches should be provided in critical areas.

9. Booster recovery will be considered only secondarily, i.e., if it doesn't slow up the development program.

10. DOD help or facilities should be considered.

11. High reliability escape and abort capabilities will be stressed.

PROGRAM ELEMENTS

The tasks which comprise the total program are grouped into the following six major categories, each of which is programmed separately and treated separately in the detailed report.

1. The manned spacecraft, including its instrumentation, life support equipment, etc.

2. The launch vehicles (including alternative and/or backup approaches) and the spacecraft propulsion system for moon landing and take-off.

3. Ground support facilities, including those for hardware development, launch, tracking and data acquisition and advanced research.

4. Life sciences, including investigation of the effects of the space and lunar environment on man and his tolerance levels and the requirements for his protection and functioning.

5. Space science prerequisites, including probes and space vehicles for investigating the cis-lunar and moon surface environment.

6. Advanced technology programs to obtain knowledge needed in the design, development of vehicle systems and in the protection of man against reentry heating and radiation.

USE OF THE SEQUENCED MILESTONE SYSTEM

The NASA Sequenced Milestone System (SMS) was used as a planning aid to interrelate the program elements and to develop the master flight plan. The SMS is an adaptation of the well established Navy PERT System which has the following features:

a. A network of activities (tasks) and miletones placed in a dependent sequence.

b. The use of data processing equipment to determine critical paths (pacing items) and slack.

In the development of the master flight plan, the SMS was used to:

a. Assess relative merits of alternate approaches.

b. Identify key decision milestones and establish the latest allowable dates by when such decisions must be made.

c. Identify pacing items and test the effects of adding resources or considering parallel efforts.

d. Identify those tasks which must be started immediately.

e. Assist in determination of funding requirements and rate of funding build-up.

PROGRAM FUNDING:

Generally, the cost associated with a program is considered after the planning of the technical program and the time phasing have been completed. In this study, a different approach was used in that budget figures were derived early in the effort and continually revised as the technical program and its schedule developed on a day to day basis. The entire budget is keyed to the Sequenced Milestone System (SMS),

adjustments being made as the program schedule was changed for various elements in the SMS network. There have been three major reviews, each narrowing down the range of budget figures. The final "hard numbers" are presented in the summary report and elaborated on in the detailed report.

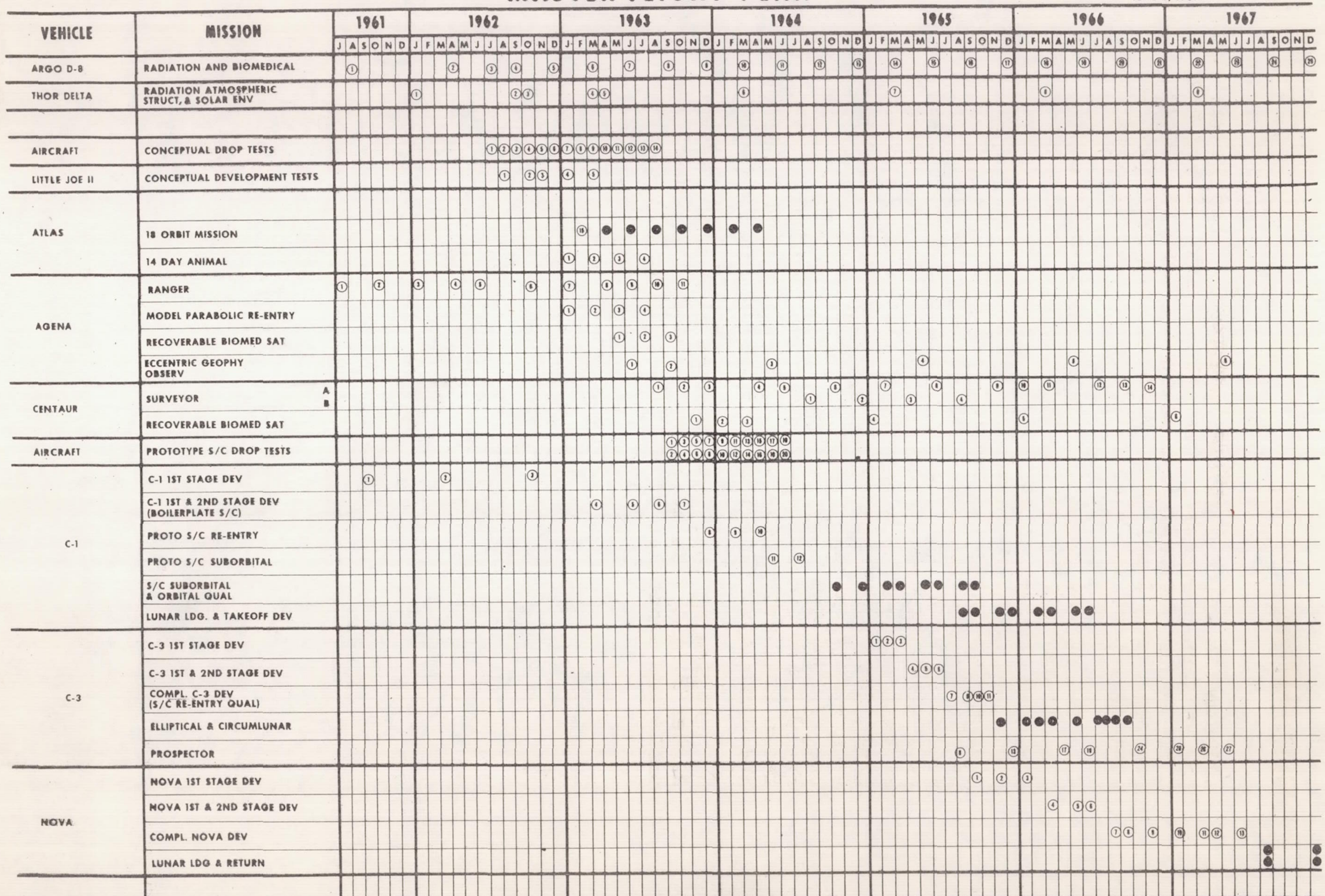
The budget presented is a "requirements budget" in that it is built from the bottom up. No arbitrary ceiling has been imposed on any of the groups working on the program. It has been carefully built up from the bits and pieces comprising the technical program and limited only by the assumed rates with which NASA and industry can be geared up to do the job and spend the money in the early part of the program. Hundreds of hours have been spent at NASA Headquarters and the field centers and data in great detail has been developed, reviewed and coordinated. As a result, a high degree of confidence can be placed in the FY 1962 and 1963 figures. The projected costs beyond FY 1963 are considered an order of magnitude better than those ordinarily developed for such a span of years as are associated with this program.

Following this introduction is a chart showing the Master Flight Plan which coordinates the launch requirements and schedules of all the program elements.

~~CONFIDENTIAL~~

MASTER FLIGHT PLAN

JUNE 9, 1961



○ UNMANNED FLIGHTS ● MANNED FLIGHTS ~~CONFIDENTIAL~~

CONFIDENTIAL

PART II

SECTION A

SPACECRAFT DEVELOPMENT PROGRAM

FOR

EARLY MANNED LUNAR LANDING

JOHN H. DISHER - HQ. OSFP
MERLE G. WAUGH - HQ. OSFP
KENNETH KLEINKNECHT - STG
ALAN B. KEHLET - STG

NASA

JUNE 16, 1961

CONFIDENTIAL

S P A C E C R A F T

Introduction

The Apollo spacecraft for the manned lunar landing mission has been under study for approximately 18 months. This study has been carried out both in-house and under contract by industry. Prior to the presently planned program acceleration, the Project Apollo spacecraft was intended to accomplish earth-orbital flight in 1966-67; fly a circumlunar mission in the 1968-69 time period; and be adaptable to a manned lunar landing mission in the post 1970 time period. The spacecraft was to be compatible with the Saturn C-1 for earth-orbital missions, the Saturn C-2 for the circumlunar mission and propulsion for the eventual lunar landing mission was not specified. With the present accelerated plan, the goals of Apollo remain unchanged but are to be carried out prior to 1970. Results of the in-house and contractual studies have been of great help in the present exercise. The completion of the contractor studies and final reporting thereon on May 15, 16 and 17 was particularly timely. The following discussion of spacecraft requirements has drawn heavily on these study results, references 1, 2 and 3.

Spacecraft Configuration

A typical spacecraft configuration for the earth orbit, circumlunar and lunar landing missions is shown in figure 1. Stringent weight limitations and the severe heating problem associated with atmospheric reentry at near-parabolic velocity have dictated the choice of the compact lifting body type of reentry vehicle. Studies have indicated that such a configuration produces adequate lift ($L/D \sim \frac{1}{2}$) for maneuver in the atmosphere and provides for satisfactory reentry corridor depth.

Attached to the reentry vehicle, as shown for the circumlunar configuration of figure 1, is an onboard propulsion system for mid-course correction, mission abort, and for take-off from the lunar surface. Although high energy propellants would pay off significantly in this system, the use of a storable propellant

system such as the Agena has been assumed in the present study. For the earth orbit or circumlunar missions, the size of the on-board propulsion system required is determined by abort requirements. For the lunar landing mission, the same propulsion system as used in the circumlunar mission can be used for lunar take-off, but additional propellant must be carried. For the landing mission, the lunar take-off propulsion could be used for abort at any time during the flight, including the period during actual lunar landing maneuver.

The lunar landing propulsion system, shown schematically in the lunar landing configuration of figure 1, will use hydrogen and oxygen as propellants. The lunar landing maneuver may be either tangential as illustrated in figure 2 or vertical. Relative merits of the alternate approaches are presently being assessed. Should the tangential landing technique be chosen, a similar take-off maneuver, as illustrated in figure 3, would be used.

Certainly a crucial task in the entire spacecraft design and development is to devise a vastly simplified and reliable launch system for departure from the lunar surface. It will be required that the system be self-contained within the spacecraft and be readily operated by three men on a precise schedule. It is considered that a lunar simulation chamber on earth which can contain the entire spacecraft and expose it to simulated lunar conditions will be an essential tool in the development of this system. It should be possible for the crew to work outside the spacecraft, enter, countdown, and possibly light off the lunar launch propulsion system in the simulator chamber. Only by so doing can the necessary high reliability of this system be attained prior to flight.

Reentry Heating

Uncertainties in the design assumptions for reentry heating at parabolic velocity will be covered by allowing adequate weight margin for ablation heat shielding and structure. Design studies for typical Apollo reentry vehicles have determined that on the basis of the best theoretical analyses available today, a heat shield weight of about 20 to 25 per cent of the reentry vehicle weight is required. The greatest uncertainty in this estimate is due to the unknown degree of nonequilibrium radiation heat flux. The design study of reference 1 has concluded that in the worst case the percentage of heat shield weight might increase to 30 or 35 per cent of reentry weight. Adequate margin is provided in the present study to cover this extreme case. In addition, the reentry

vehicle development program is phased such that the critical heating data from large-scale flight experiments will be available prior to the need for final specification of the heat shield design for reentry at parabolic velocity. During the orbital phase of the Apollo program, a heat shield, which is analytically capable of reentry at parabolic velocity and which is known from experience to be satisfactory for reentry from orbit, will be fitted to the spacecraft. If necessary, the heat shield can subsequently be changed prior to higher velocity flights with the production Apollo spacecraft.

Radiation Shielding

Calculations indicate that solar flares present the major radiation hazard to manned lunar flight. The spacecraft structure and equipment inherently provide adequate shielding against most solar flares. However, in order to limit dosage to 25 REM for the more intense flares, a moderate amount of shielding must be added to that afforded by the basic spacecraft. Depending on the spacecraft configuration, the shielding weight could either be built into the walls of the vehicle or fitted about the individual crew members in the form of quick-don water filled garments. Based on present knowledge, approximately 1,200 pounds of added shielding would be adequate for all but the so-called giant flares. For these "giant" events, the low probability of occurence and the fact that with the amount of shielding provided, a giant flare would not result in a lethal dosage to the crew, appear to make the risks associated with even giant flares acceptably low.

If the capability to predict large solar flares 2 or 3 days ahead of time could be developed, the risk associated with these events could be further reduced. Substantial effort in this regard is under way.

Weightlessness

The Apollo spacecraft development effort will be based on the assumption that artificial gravity is not required. There are already indications that this assumption may well be a reasonable one. Shepard's five-minute flight, and Gagarin's ninety-minute flight have demonstrated that short flights have no deleterious physiological effects.

Programs are under way to establish the effects on man of prolonged weightlessness. In 1962, Mercury $4\frac{1}{2}$-hour missions will be flown. These will be followed, in late 1962 or early 1963, by 27-hour flights. Hopefully, detailed information from Soviet flights will also become available in this time period.

Early in 1963, also, 14-day flights with primates will be made.

Data from all of these flights will establish whether or not the assumption to proceed without artificial gravity is valid.

Concurrent with the main effort, developing a spacecraft without artificial gravity, a backup effort of a spacecraft with artificial gravity should be initiated. In this effort, parametric design studies will be carried out during the first half of 1962. A design and engineering effort can be completed by the end of 1963. By that time, full information will be available concerning the effects of weightlessness, and a final decision can be made as to whether to proceed with either the main effort (no artificial g) or the backup effort (with artificial g).

Spacecraft Weight

A spacecraft weight of 12,500 pounds has been set forth for determining minimum booster requirements for the circumlunar and lunar landing missions. This 12,500 pound weight includes spacecraft attitude control but no other propulsion allowance. The weight breakdown is shown and compared with study results in figure 4.

The 12,500 pound spacecraft weight provides a contingency of 1,600 pounds over the weight which the study results have indicated to be required. This contingency is felt necessary to provide for possible underestimation of the heat input from nonequilibrium radiation heating during reentry and to provide for less refined and, thus, heavier systems resulting from the presently accelerated developmental timetable. In addition, whereas the study results allowed no weight expressly for protecting the crew from radiation hazards, the present exercise has allowed 1,200 pounds for this purpose.

The combined weight of the spacecraft and abort or lunar launch propulsion system is shown in figure 5. For the circumlunar mission, 12,500 pounds of propulsion system weight is

necessary to provide the desired rapid return to earth in case of an aborted flight at any time up to injection and 2-day maximum return time during most of the mission. The 12,500 pound abort system with storable propellants would provide a velocity increment of about 5,000 feet per second and a return time of about 3 hours for abort at injection.

The lunar orbit would be a desirable but not essential mission following the basic circumlunar flight. Lunar orbit capability could be attained within the 25,000 pound payload if the onboard propulsion were hydrogen-oxygen rather than storable or if the spacecraft weight contingency turned out not to be needed. However, to insure lunar orbit capability with the 12,500 pound spacecraft and storable propellants, a propulsion system weight of about 17,500 pounds and total injected weight of about 30,000 pounds would be required.

It is apparent that with the presently projected spacecraft weight, the circumlunar mission is not feasible with the Saturn C-2 launch vehicle unless the desired abort capability were to be sacrificed. Both the circumlunar and lunar orbit missions, however, would be within the capability of the Saturn C-3 launch vehicle.

For the lunar launch, using storable propellants with 300 seconds specific impulse, a lunar take-off weight of 53,000 pounds has been conservatively estimated as required for the 12,500 pound spacecraft.

This weight is based on the provision of a velocity increment of 10,800 feet per second for lunar escape and mid-course correction, and an empty weight, with residuals, of 4,500 pounds for the lunar departure propulsion. This weight assumption is based on a propellant mass fraction of .89 which is representative of the Agena, Centaur and S-IV stages. The 10,800 feet per second is determined as follows:

60-hour return trajectory with gravity loss	9,750 ft/sec
Mid-course	500 ft/sec
Reserve for non-ideal maneuvers	550 ft/sec
	10,800 ft/sec

Both the mass fraction and velocity requirement assumed are somewhat conservative. For purposes of comparison, more optimistic assumptions of a propellant mass fraction of .92 and velocity requirement of 10,000 feet per second lead to a lunar departure weight of only 42,000 pounds.

As discussed in the propulsion section of this document, the 53,000 pound lunar departure weight would require an earth escape injected weight of about 150,000 pounds. On the other hand, the 42,000 pound lunar departure weight would require only about 115,000 pounds injected weight.

Development Phasing

Shown in figure 6 is a broad outline of the spacecraft development phasing. It is planned that the spacecraft contract be let by January, 1962, and that first orbital tests be made in late 1964. Concurrent with the spacecraft development and production, similar activity will be under way on the lunar launch and abort propulsion and the lunar landing propulsion systems. The first earth-orbital flights of the spacecraft may use interim solid propellant retro-rockets for return from orbit. During the spacecraft development period, flight data on weightlessness, radiation, and reentry heating will become available at the times indicated.

Following successful completion of the earth-orbital phase of the program, elliptical orbit and circumlunar flights will be undertaken. Concurrent with these flights, development flights of the lunar landing and take-off system will be made by carrying out simulated lunar landings at a point in space. These flights would require ballistic launch to the simulated lunar approach conditions. Following successful completion of the circumlunar and simulated landing flights, the actual manned lunar landing mission would be undertaken on the Nova vehicle. This might be as early as the eleventh Nova vehicle if all goes well or on the fourteenth vehicle if the first thirteen are required for Nova development.

PERT System

A simplified PERT network, figure 7, was constructed for each of the flight test programs required in developing an Apollo spacecraft suitable for the lunar landing mission. The milestones

selected were similar in each network and simply were key points in the contracting, engineering design, fabrication, and check-out of the specific spacecraft. The apparent complexity in the networks stems merely from the creation of a separate path leading to the launch of each individual spacecraft. The time estimates linking the milestones were, for the most part, based on Mercury experience. Tabulated results of the several network computations are shown in figure 8. The most pertinent result on each figure is the indication of slack in column 5. Negative slack indicates the actual time required is longer than that allowed by the desired schedule. Positive slack, of course, indicates time to spare for a particular task.

18-Orbit Mission

The critical path in the network describing the design, fabrication and preparation for launch of 18-orbit Mercury capsules, lies in the procurement of the third 18-orbit Mercury capsule. This program is well along in planning at Space Task Group and a preliminary study of what is required is under way at McDonnell Aircraft Corporation. However, the time available to complete a sound engineering design and to get fabrication under way is a minimum. For this reason, it is considered mandatory to place this program under contract as soon as possible, and effort to accomplish this is now being expedited at Space Task Group.

14-Day Animal Program

The 14-Day Animal Program will also utilize the Mercury capsule, modified to provide control and life support for an animal payload for a 14-day period. The critical path is, in this simplified analysis, simply the time required to design, fabricate and check out the initial spacecraft. While this program does not appear as critical as the 18-Orbit Mission, when the detail of the PERT analysis is increased, some subsystem procurement may turn out to require more time than is presently estimated. At this time, however, the program does not appear to be fundamentally different from Mercury and time estimates are based on Mercury experience. It is tentatively planned to assign management of this program to the Ames Research Center.

Model Reentry Tests

The time available to meet the Master Flight Plan schedule for the Model Reentry Tests is the same as for the 14-Day Animal program. In this series of tests, four spacecraft are required to obtain fundamental test data on reentry heating phenomenon required for development of the Apollo spacecraft reentry configuration. NASA rocket testing experience will directly apply to this series of tests and it is planned to assign this program to the Langley Research Center. Langley is presently preparing a preliminary development plan for the project. The PERT network shows that the critical path is that leading through procurement of subsystems and terminating in the performance of the third flight test.

Recoverable Biomedical Satellites

This program initially involves launching six special biomedical satellite spacecraft, on two types of launch vehicles, Atlas-Agena B and Centaur, through FY 1964. A follow-on series of launches, one per year through 1967 is also planned. Planning at this time has not progressed to the point where any firm spacecraft design can be specified. The critical path as shown in the Recoverable Biomedical Satellite PERT network will, of course, depend upon whether an existing spacecraft such as Mercury can be utilized and the modifications which must be incorporated. Decisions are required as soon as practicable on program funding and how the program will be managed. Subsequent to this, detailed planning will result in more firm estimates of times required to do the job. The times between milestones shown on the PERT network do however reflect both Mercury experience and experience with other NASA and DOD satellite programs. It is assumed that one of the research centers can take on the job of managing this program as in the 14-Day Animal and Model Reentry Test Program.

Apollo Spacecraft (including the Onboard Spacecraft Propulsion Systems)

The primary spacecraft effort in the Apollo program is, of course, the development of the Apollo Command Center and of the Onboard Propulsion required to provide mid-course flight path correction, a capability for landing on the lunar surface and subsequent launching from the moon and return to earth. Also included is the early development and qualification of a launch

escape propulsion system (LEPS). The Apollo Spacecraft network describes the total development of these elements of the Apollo Program. The several types of Apollo spacecraft flights described in the Master Flight Plan are designed to logically verify the adequacy of various performance characteristics of the Apollo spacecraft, as early as possible, to insure availability of a completely qualified design in time for the scheduled lunar landing missions. The supporting flight programs, those described above and the many scientific and exploratory flights described elsewhere, all will provide data in support of the primary effort. It is presumed, however, that the primary effort can go along at its own pace and that only when results from the supporting flights indicate that the design is unsatisfactory, will these results change the course of the primary effort. Therefore, the time estimates between milestones have been based on what can be expected in an intensive straightforward engineering development. It is planned to make several preliminary prototype configurations of the command center available during the development, for test and qualification of various subsystems. Final verification of the design can be completed shortly after parabolic reentry testing utilizing the C-3 launch vehicle and following these tests, the Apollo Spacecraft will stabilize into a production configuration.

Networks for the lunar landing and lunar launch or abort propulsion systems are included with the spacecraft, figures 7 and 8. However, a discussion of the development phasing of these systems is presented in the propulsion section of the present study.

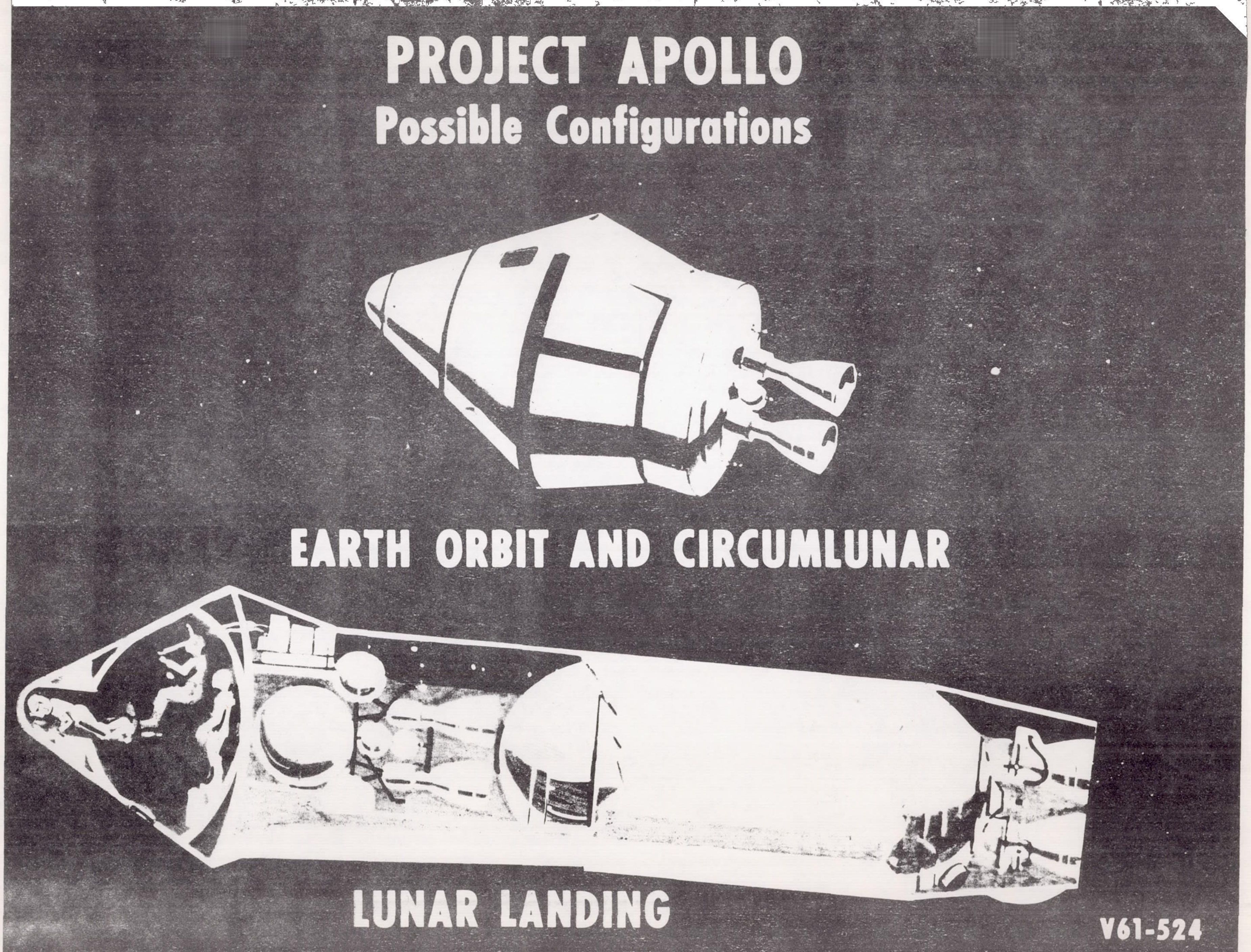
The initial PERT network for the Apollo spacecraft and related onboard propulsion systems showed that the onboard propulsion systems development determined the critical path. However, with the assumptions made, the spacecraft and onboard propulsion systems would, at every point, be ready in time to meet the Master Flight Plan schedule, which was determined by launch vehicle availability. Thus, insofar as the over-all plan is concerned, the critical path is launch vehicle development. That such would be expected to be the case is amply borne out by Project Mercury experience.

REFERENCES

1. Apollo Feasibility Study, Final Report, May 15, 1961.
   Convair Astronautics Division, General Dynamics Corporation.

2. Apollo Feasibility Study, Final Report, May 15, 1961.
   General Electric Missiles and Space Vehicles Department.

3. Apollo Feasibility Study, Final Report, May 15, 1961.
   The Martin Company.


PROJECT APOLLO
Possible Configurations
EARTH ORBIT AND CIRCUMLUNAR
LUNAR LANDING
V61-524


LUNAR LANDING
S61-46T
19


LUNAR TAKEOFF
21

FIGURE 4

SPACECRAFT WEIGHTS

	STUDIES	ALLOWED
STRUCTURE & HEAT PROTECTION	5100	6600
POWER SUPPLY	1000	1000
CREW & ENV. CONTROL SYSTEM	1700	1700
GUIDANCE AND CONTROL	1400	1400
COMMUNICATIONS AND INSTRUMENTATION	550	550
RADIATION SHIELDING	—	1250
	9700 LBS	12,500 LBS

MISSION WEIGHTS

	Circumlunar	Lunar Orbit
Spacecraft without propulsion	12,500 lbs.	12,500 lbs.
Propulsion system empty weight	2,500 lbs.	2,500 lbs.
Useable propellant (storable)	10,000 lbs.	15,000 lbs.
Available velocity increment	5,000 ft/sec	6,700 ft/sec
TOTAL INJECTED WEIGHT	25,000 lbs.	30,000 lbs.

Figure 5. Circumlunar and lunar orbit mission weights.

SPACECRAFT PHASING

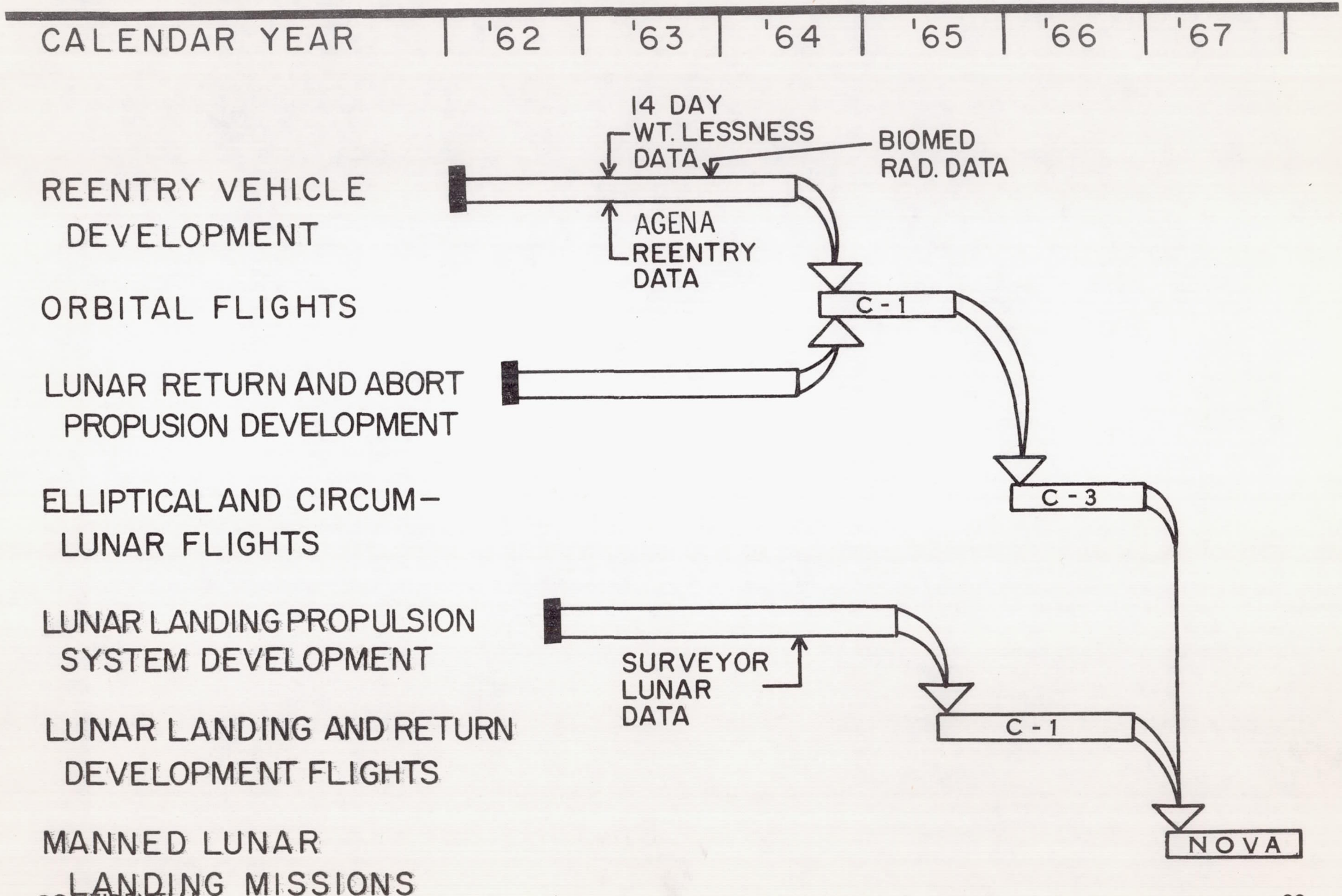


FIGURE 7a
CHART 50

LUNAR LANDING SPACECRAFT

(995-000-000)
CHART 1 OF 5
6/7/61

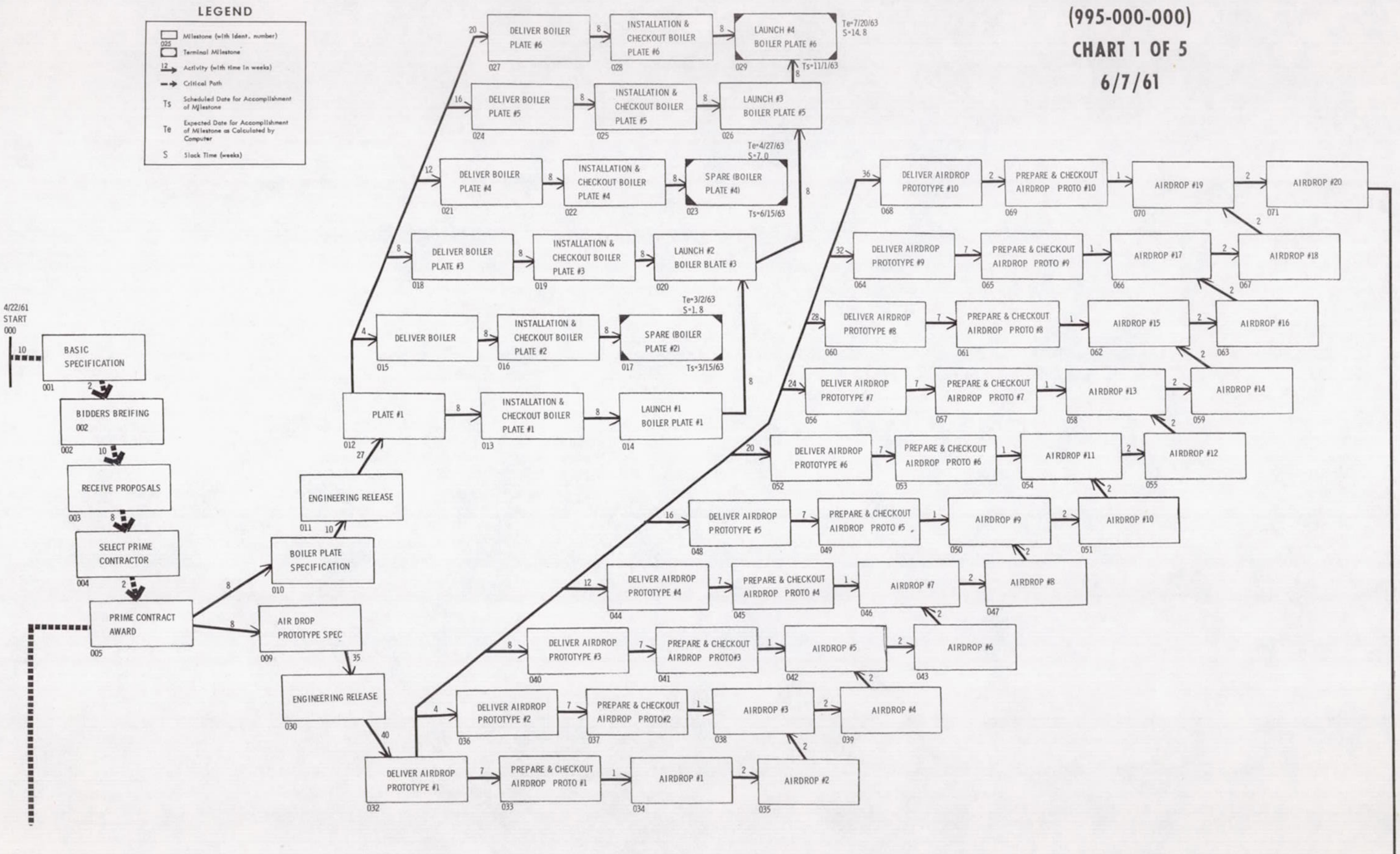
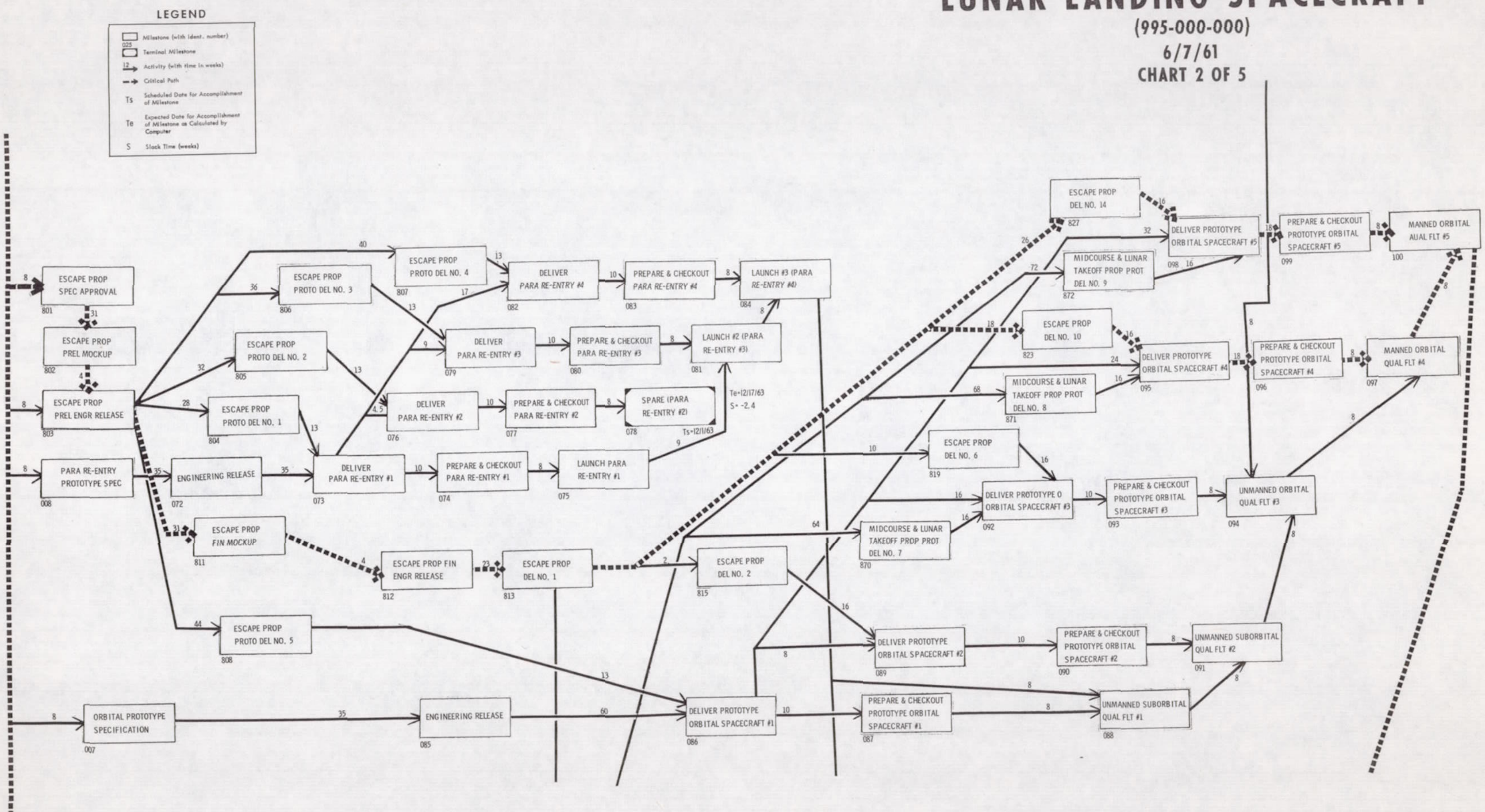


FIGURE 7a
CHART 50

LUNAR LANDING SPACECRAFT

(995-000-000)
6/7/61
CHART 2 OF 5



CONFIDENTIAL

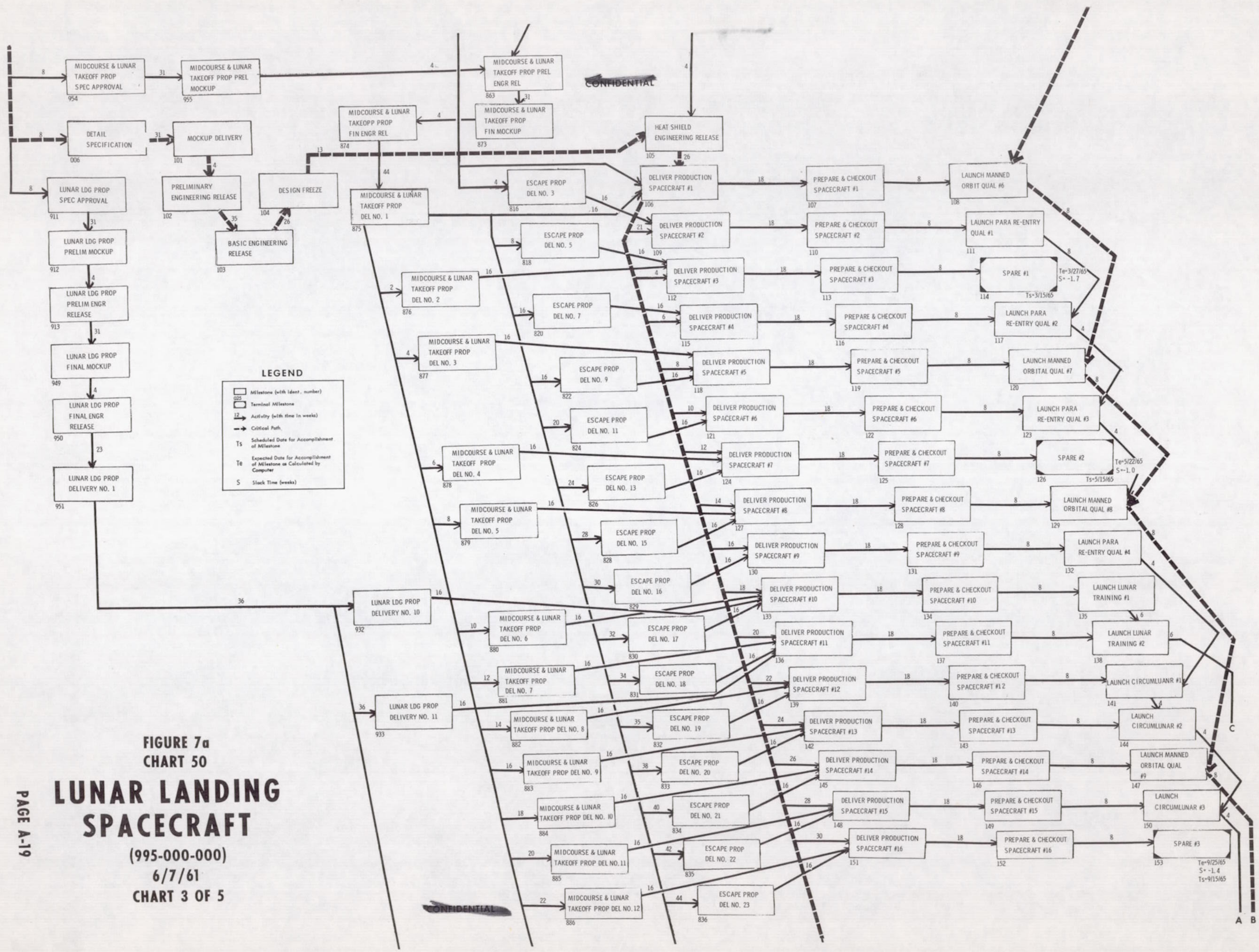


FIGURE 7a
CHART 50

LUNAR LANDING SPACECRAFT

(995-000-000)
6/7/61
CHART 3 OF 5

CONFIDENTIAL

CONFIDENTIAL

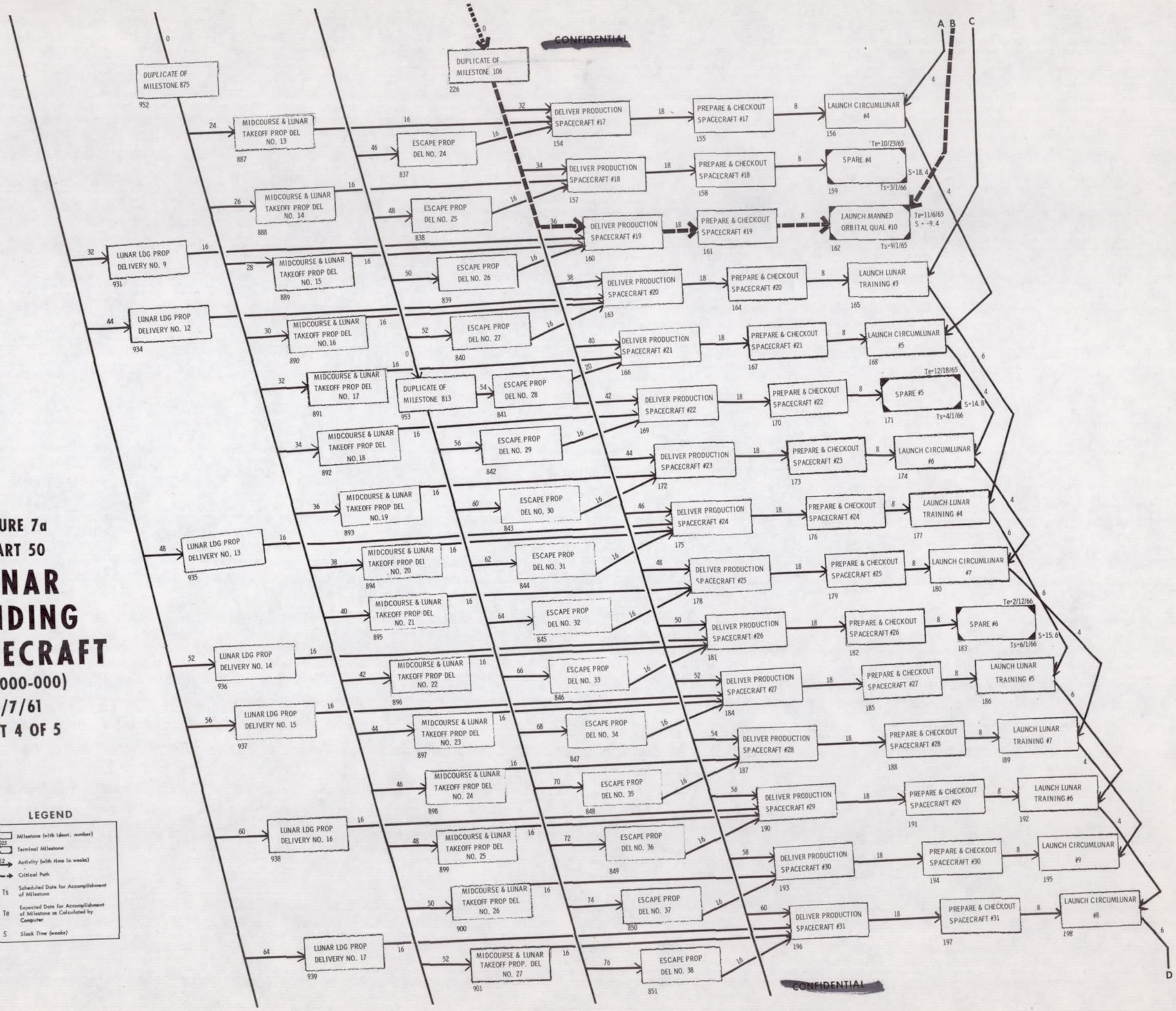


FIGURE 7a
CHART 50

LUNAR LANDING SPACECRAFT

(995-000-000)
6/7/61
CHART 4 OF 5

LEGEND

- Milestone (with ident. number)
- Terminal Milestone
- Activity (with time in weeks)
- Critical Path
- Ts — Scheduled Date for Accomplishment of Milestone
- Te — Expected Date for Accomplishment of Milestone as Calculated by Computer
- S — Slack Time (weeks)

CONFIDENTIAL

CONFIDENTIAL

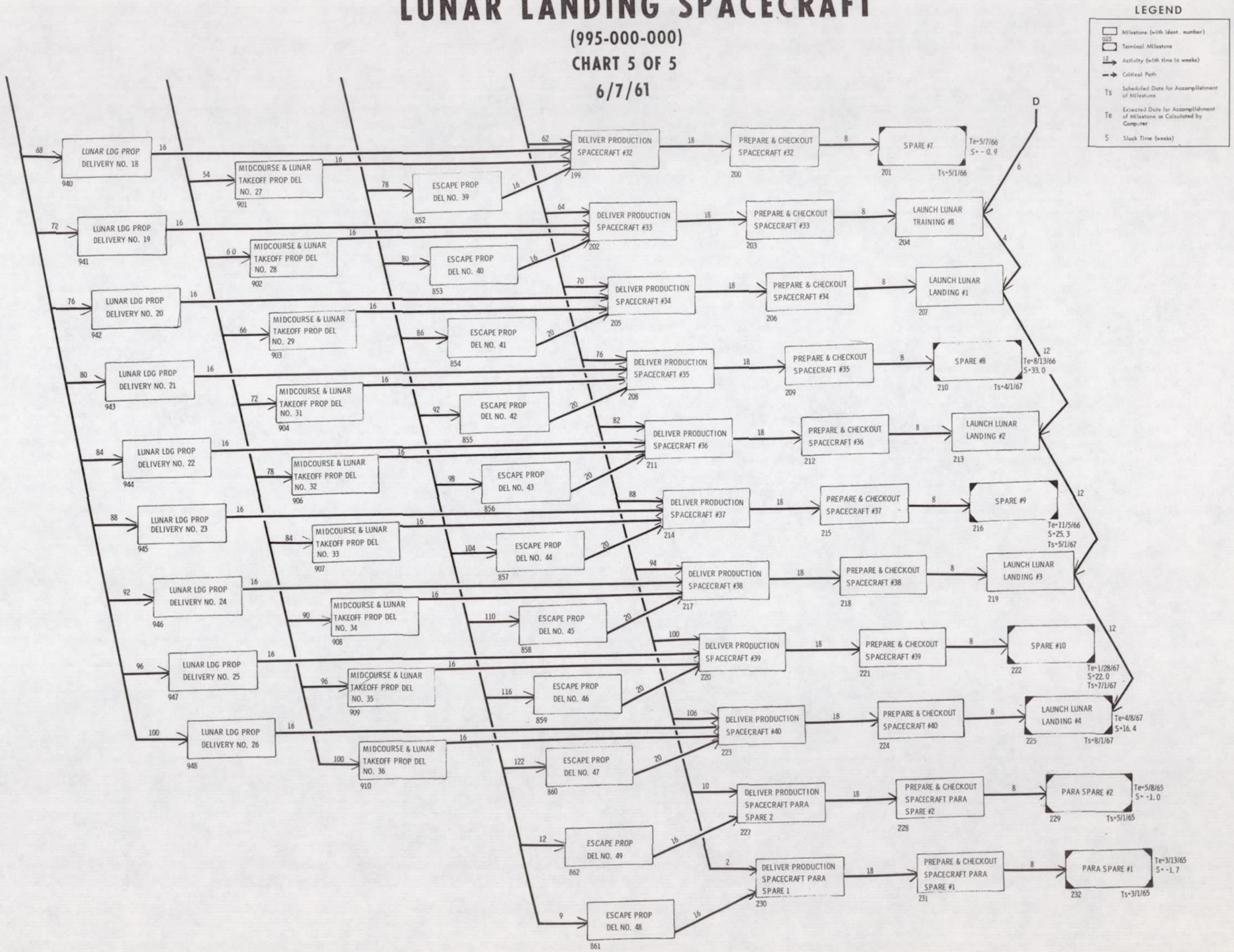
CHART 50 FIGURE 7a

LUNAR LANDING SPACECRAFT

(995-000-000)

CHART 5 OF 5

6/7/61



CONFIDENTIAL

[redacted]

FIG. 7B

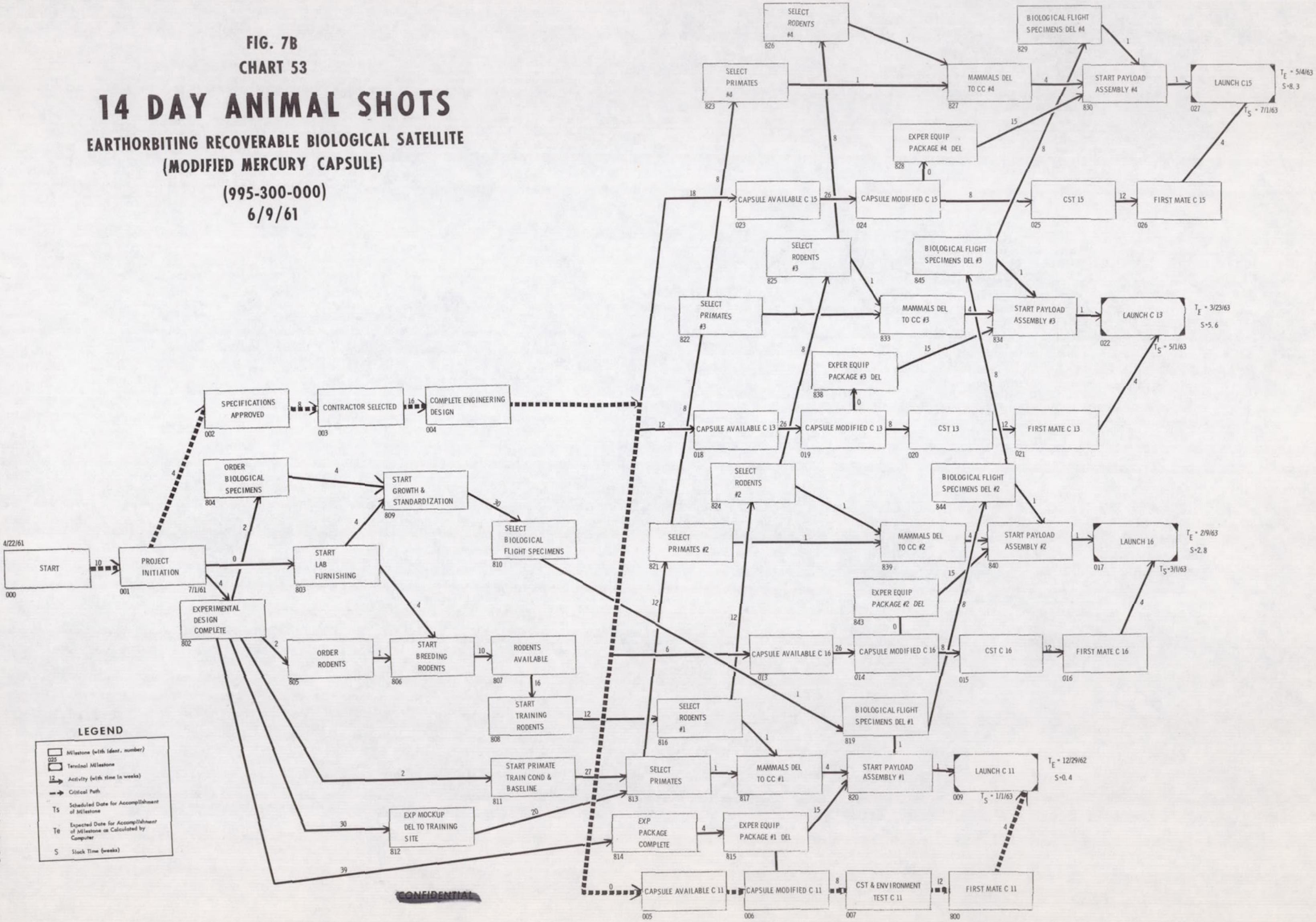
CHART 53

14 DAY ANIMAL SHOTS

EARTHORBITING RECOVERABLE BIOLOGICAL SATELLITE
(MODIFIED MERCURY CAPSULE)

(995-300-000)

6/9/61



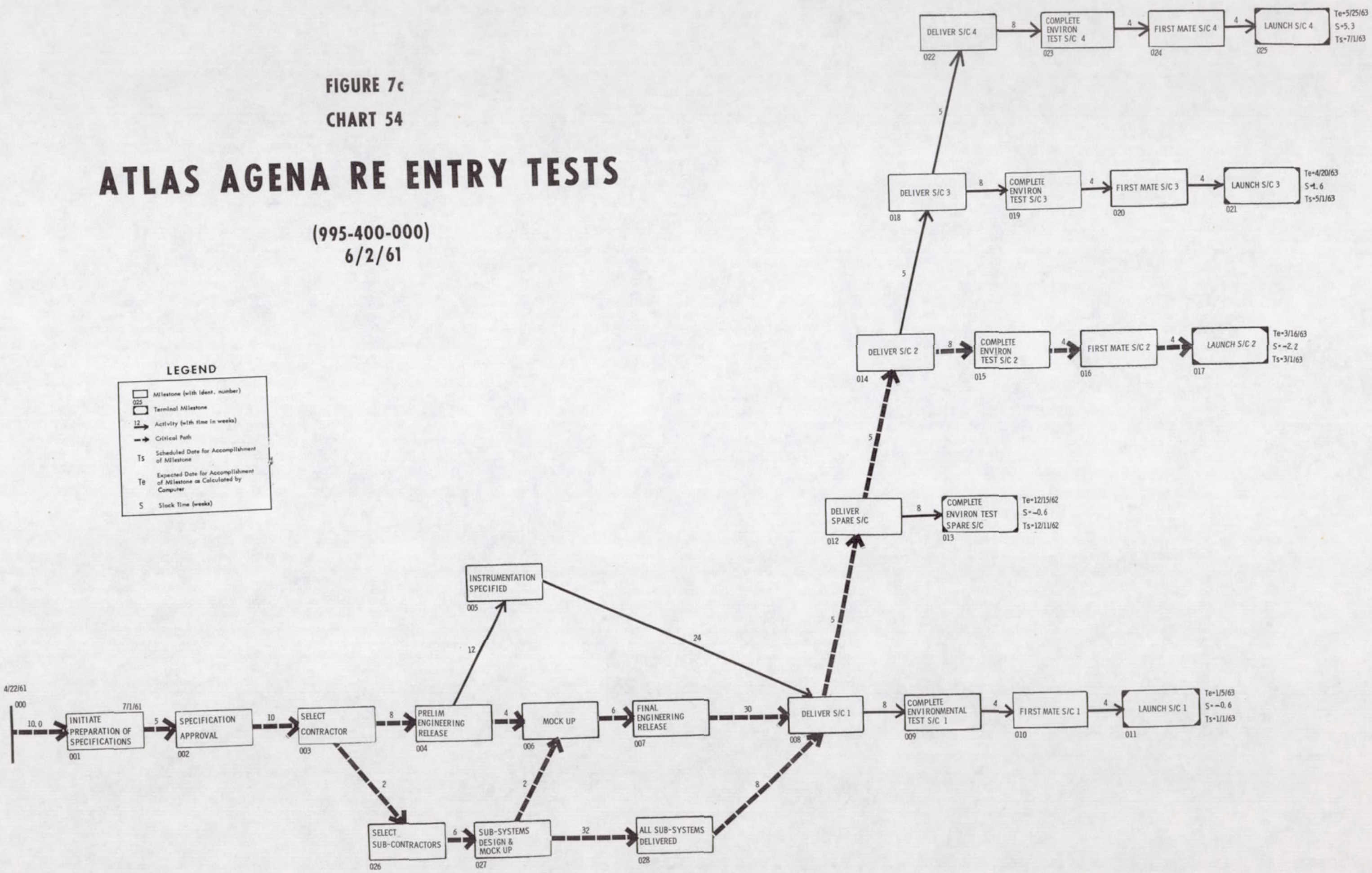
[redacted]

FIGURE 7c

CHART 54

ATLAS AGENA RE ENTRY TESTS

(995-400-000)
6/2/61



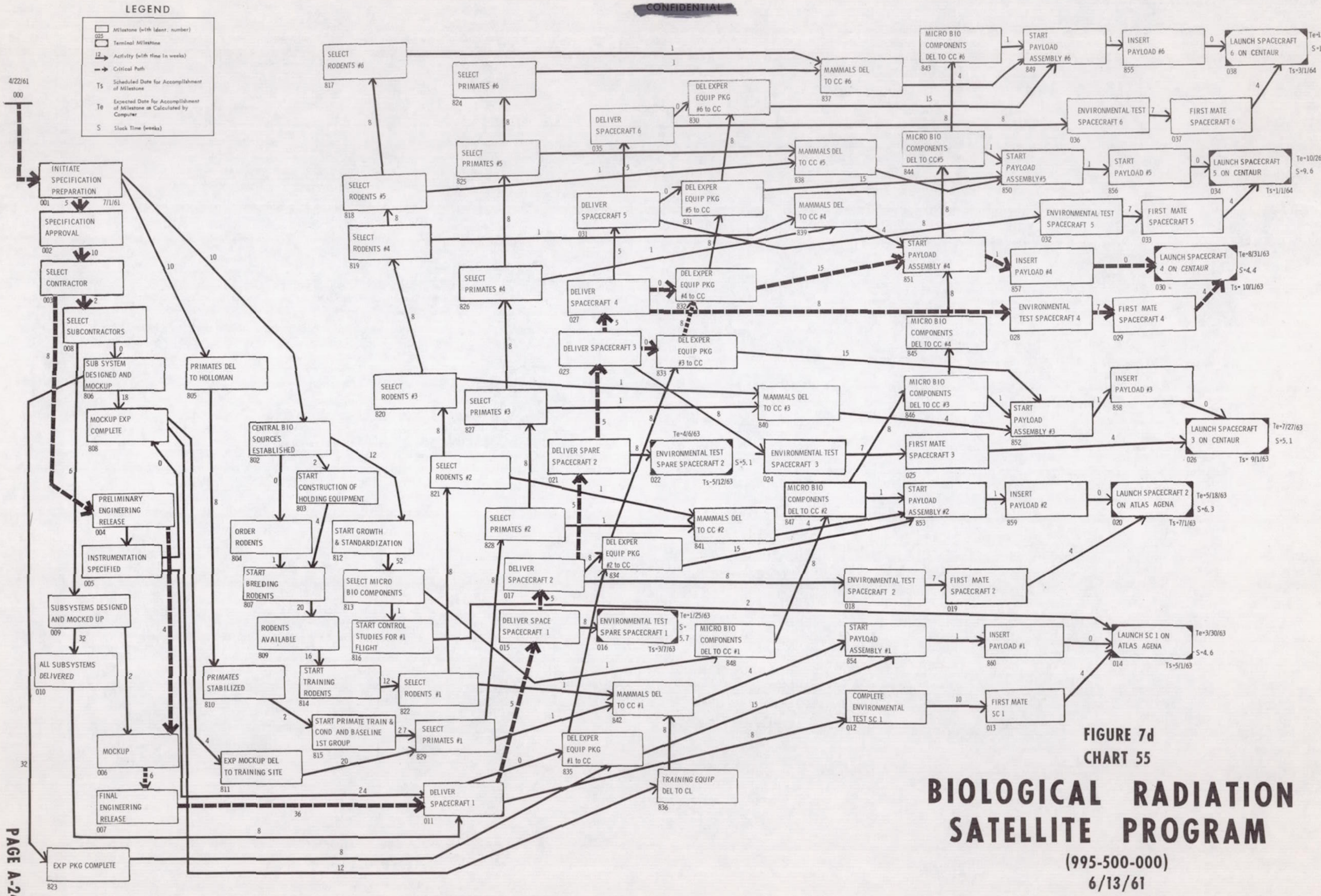


FIGURE 7d
CHART 55

BIOLOGICAL RADIATION SATELLITE PROGRAM

(995-500-000)
6/13/61

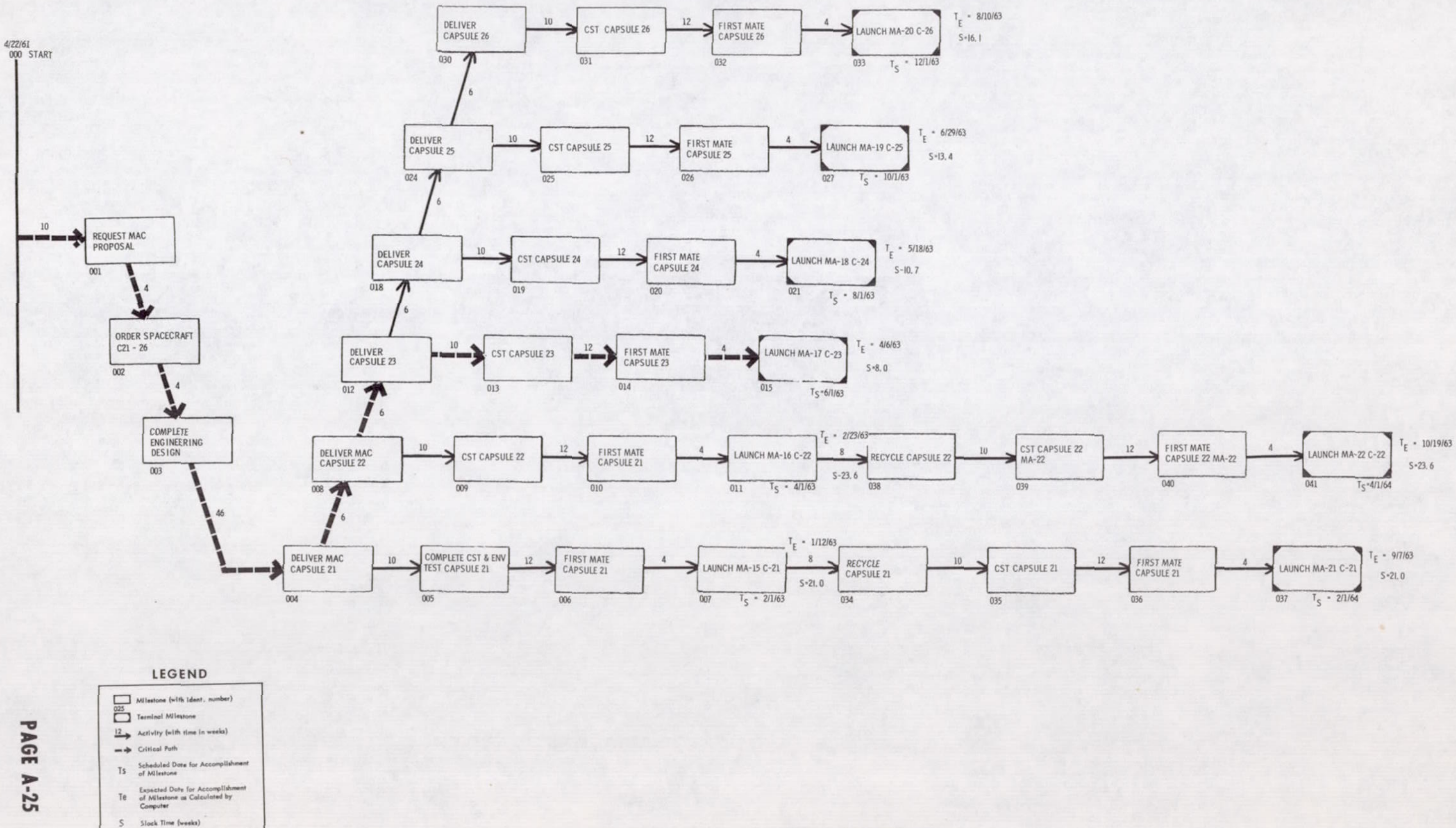
FIGURE 7-e

CHART 57

18 ORBIT MISSION

(995-700-000)

6/2/61



CONFIDENTIAL

SMS SYSTEM

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-000	NOT TITLED	0/00/00	0/00/00			- 9.4
995-000-001	NOT TITLED	7/01/61	4/26/61			- 9.4
995-000-002	NOT TITLED	7/15/61	5/10/61			- 9.4
995-000-003	NOT TITLED	9/23/61	7/19/61			- 9.4
995-000-004	NOT TITLED	11/18/61	9/13/61			- 9.4
995-000-005	NOT TITLED	12/02/61	9/27/61			- 9.4
995-000-801	ESCAPE PROP SPEC APPROVAL	1/27/62	11/22/61			- 9.4
995-000-006	NOT TITLED	1/27/62	11/22/61			- 9.4
995-000-802	ESCAPE PROP PREL MOCKUP	9/01/62	6/27/62			- 9.4
995-000-101	NOT TITLED	9/01/62	6/27/62			- 9.4
995-000-803	ESCAPE PROP PREL ENGR RELEASE	9/29/62	7/25/62			- 9.4
995-000-102	NOT TITLED	9/29/62	7/25/62			- 9.4
995-000-811	ESCAPE PROP FIN MOCKUP	5/04/63	2/27/63			- 9.4
995-000-103	NOT TITLED	6/01/63	3/27/63			- 9.4
995-000-812	ESCAPE PROP FIN ENGR RELEASE	6/01/63	3/27/63			- 9.4
995-000-813	ESCAPE PROP DEL NO 1	11/09/63	9/04/63			- 9.4
995-000-104	NOT TITLED	11/30/63	9/25/63			- 9.4
995-000-823	ESCAPE PROP DEL NO 10	3/14/64	1/08/64			- 9.4
995-000-105	NOT TITLED	4/25/64	2/19/64			- 9.4
995-000-827	ESCAPE PROP DEL NO 14	5/09/64	3/04/64			- 9.4
995-000-095	NOT TITLED	7/04/64	4/29/64			- 9.4
995-000-226	NOT TITLED	8/29/64	6/24/64			- 9.4
995-000-106	NOT TITLED	8/29/64	6/24/64			- 9.4
995-000-098	NOT TITLED	8/29/64	6/24/64			- 9.4
995-000-096	NOT TITLED	11/07/64	9/02/64			- 9.4

CONFIDENTIAL

Figure 8a

CONFIDENTIAL

SMS SYSTEM

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-099	NOT TITLED	1/02/65	10/28/64			- 9.4
995-000-097	NOT TITLED	1/02/65	10/28/64	12/01/64		- 9.4
995-000-100	NOT TITLED	2/27/65	12/23/64	2/01/65		- 9.4
995-000-108	NOT TITLED	4/24/65	2/17/65	3/01/65		- 9.4
995-000-160	NOT TITLED	5/08/65	3/03/65			- 9.4
995-000-120	NOT TITLED	6/19/65	4/14/65	5/01/65		- 9.4
995-000-129	NOT TITLED	8/14/65	6/09/65	6/01/65		- 9.4
995-000-161	NOT TITLED	9/11/65	7/07/65			- 9.4
995-000-147	NOT TITLED	9/11/65	7/07/65	8/01/65		- 9.4
995-000-162	NOT TITLED	11/06/65	9/01/65	9/01/65		- 9.4
995-000-804	ESCAPE PROP PROTO DEL NO 1	4/13/63	2/20/63			- 7.4
995-000-073	NOT TITLED	7/13/63	5/22/63			- 7.4
995-000-079	NOT TITLED	9/14/63	7/24/63			- 7.4
995-000-074	NOT TITLED	9/21/63	7/31/63			- 7.4
995-000-082	NOT TITLED	11/09/63	9/18/63			- 7.4
995-000-075	NOT TITLED	11/16/63	9/25/63	12/01/63		- 7.4
995-000-080	NOT TITLED	11/23/63	10/02/63			- 7.4
995-000-083	NOT TITLED	1/18/64	11/27/63			- 7.4
995-000-081	NOT TITLED	1/18/64	11/27/63	2/01/64		- 7.4
995-000-084	NOT TITLED	3/14/64	1/22/64	4/01/64		- 7.4
995-000-145	NOT TITLED	2/27/65	1/06/65			- 7.4
995-000-146	NOT TITLED	7/03/65	5/12/65			- 7.4
995-000-806	ESCAPE PROP PROTO DEL NO 3	6/08/63	4/24/63			- 6.4
995-000-954	MIDCOURSE & LUNAR TAKEOFF PROP SPEC APPROVAL	1/27/62	12/27/61			- 4.4
995-000-955	MIDCOURSE & LUNAR TAKEOFF PROP PREL MOCKUP	9/01/62	8/01/62			- 4.4

CONFIDENTIAL

Figure 8a

CONFIDENTIAL

SMS SYSTEM

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-863	MIDCOURSE & LUNAR TAKEOFF PROP PREL ENGR REL	9/29/62	8/29/62			- 4.4
995-000-873	MIDCOURSE & LUNAR TAKEOFF PROP FIN MOCKUP	5/04/63	4/03/63			- 4.4
995-000-874	MIDCOURSE & LUNAR TAKEOFF PROP FIN ENGR REL	6/01/63	5/01/63			- 4.4
995-000-875	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 1	4/04/64	3/04/64			- 4.4
995-000-109	NOT TITLED	9/12/64	8/19/64			- 3.4
995-000-110	NOT TITLED	1/16/65	12/23/64			- 3.4
995-000-111	NOT TITLED	3/13/65	2/17/65	7/01/65		- 3.4
995-000-117	NOT TITLED	5/08/65	4/14/65	7/29/65		- 3.4
995-000-123	NOT TITLED	6/05/65	5/12/65	8/26/65		- 3.4
995-000-807	ESCAPE PROP PROTO DEL NO 4	7/06/63	6/19/63			- 2.4
995-000-076	NOT TITLED	8/13/63	7/28/63			- 2.4
995-000-077	NOT TITLED	10/22/63	10/06/63			- 2.4
995-000-078	NOT TITLED	12/17/63	12/01/63	12/01/63		- 2.4
995-000-805	ESCAPE PROP PROTO DEL NO 2	5/11/63	4/28/63			- 1.9
995-000-230	NOT TITLED	9/12/64	8/31/64			- 1.7
995-000-112	NOT TITLED	9/26/64	9/14/64			- 1.7
995-000-231	NOT TITLED	1/16/65	1/04/65			- 1.7
995-000-113	NOT TITLED	1/30/65	1/18/65			- 1.7
995-000-232	NOT TITLED	3/13/65	3/01/65	3/01/65		- 1.7
995-000-114	NOT TITLED	3/27/65	3/15/65	3/15/65		- 1.7
995-000-008	NOT TITLED	1/27/62	1/17/62			- 1.4
995-000-007	NOT TITLED	1/27/62	1/17/62			- 1.4
995-000-072	NOT TITLED	9/29/62	9/19/62			- 1.4
995-000-085	NOT TITLED	9/29/62	9/19/62			- 1.4
995-000-086	NOT TITLED	11/23/63	11/13/63			- 1.4

CONFIDENTIAL

Figure 8a

CONFIDENTIAL

SMS SYSTEM

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-815	ESCAPE PROP DEL NO 2	11/23/63	11/13/63			- 1.4
995-000-819	ESCAPE PROP DEL NO 6	1/18/64	1/08/64			- 1.4
995-000-871	MIDCOURSE & LUNAR TAKEOFF PROP PROT DEL NO 8	1/18/64	1/08/64			- 1.4
995-000-089	NOT TITLED	3/14/64	3/04/64			- 1.4
995-000-092	NOT TITLED	5/09/64	4/29/64			- 1.4
995-000-090	NOT TITLED	5/23/64	5/13/64			- 1.4
995-000-091	NOT TITLED	7/18/64	7/08/64	8/01/64		- 1.4
995-000-093	NOT TITLED	7/18/64	7/08/64			- 1.4
995-000-094	NOT TITLED	9/12/64	9/02/64	10/01/64		- 1.4
995-000-118	NOT TITLED	10/24/64	10/14/64			- 1.4
995-000-107	NOT TITLED	1/02/65	12/23/64			- 1.4
995-000-119	NOT TITLED	2/27/65	2/17/65			- 1.4
995-000-151	NOT TITLED	3/27/65	3/17/65			- 1.4
995-000-152	NOT TITLED	7/31/65	7/21/65			- 1.4
995-000-153	NOT TITLED	9/25/65	9/15/65	9/15/65		- 1.4
995-000-227	NOT TITLED	11/07/64	10/31/64			- 1.0
995-000-124	NOT TITLED	11/21/64	11/14/64			- 1.0
995-000-228	NOT TITLED	3/13/65	3/06/65			- 1.0
995-000-125	NOT TITLED	3/27/65	3/20/65			- 1.0
995-000-229	NOT TITLED	5/08/65	5/01/65	5/01/65		- 1.0
995-000-126	NOT TITLED	5/22/65	5/15/65	5/15/65		- 1.0
995-000-199	NOT TITLED	11/06/65	10/31/65			- 0.9
995-000-200	NOT TITLED	3/12/66	3/06/66			- 0.9
995-000-201	NOT TITLED	5/07/66	5/01/66	5/01/66		- 0.9
995-000-088	NOT TITLED	5/09/64	5/13/64	6/01/64		0.6

CONFIDENTIAL

Figure 8a

CONFIDENTIAL

SMS S Y S T E M

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-115	NOT TITLED	10/10/64	10/14/64			0.6
995-000-121	NOT TITLED	11/07/64	11/11/64			0.6
995-000-127	NOT TITLED	12/05/64	12/09/64			0.6
995-000-116	NOT TITLED	2/13/65	2/17/65			0.6
995-000-122	NOT TITLED	3/13/65	3/17/65			0.6
995-000-128	NOT TITLED	4/10/65	4/14/65			0.6
995-000-808	ESCAPE PROP PROTO DEL NO 5	8/03/63	8/14/63			1.6
995-000-010	NOT TITLED	1/27/62	2/08/62			1.8
995-000-011	NOT TITLED	4/07/62	4/19/62			1.8
995-000-012	NOT TITLED	10/13/62	10/25/62			1.8
995-000-015	NOT TITLED	11/10/62	11/22/62			1.8
995-000-016	NOT TITLED	1/05/63	1/17/63			1.8
995-000-017	NOT TITLED	3/02/63	3/14/63	3/15/63		1.8
995-000-870	MIDCOURSE & LUNAR TAKEOFF PROP PROT DEL NO 7	12/21/63	1/08/64			2.6
995-000-872	MIDCOURSE & LUNAR TAKEOFF PROP PROT DEL NO 9	2/15/64	3/04/64			2.6
995-000-839	ESCAPE PROP DEL NO 26	10/24/64	11/11/64			2.6
995-000-952	NOT TITLED	4/04/64	4/29/64			3.6
995-000-889	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 15	10/17/64	11/11/64			3.6
995-000-834	ESCAPE PROP DEL NO 21	8/15/64	9/16/64			4.6
995-000-876	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 2	4/18/64	5/25/64			5.3
995-000-884	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 10	8/08/64	9/16/64			5.6
995-000-009	NOT TITLED	1/27/62	3/13/62			6.5
995-000-030	NOT TITLED	9/29/62	11/13/62			6.5
995-000-032	NOT TITLED	7/06/63	8/20/63			6.5
995-000-060	NOT TITLED	1/18/64	3/03/64			6.5

CONFIDENTIAL

Figure 8a

CONFIDENTIAL

SMS SYSTEM

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-061	NOT TITLED	3/08/64	4/22/64			6.5
995-000-062	NOT TITLED	3/15/64	4/29/64			6.5
995-000-063	NOT TITLED	3/29/64	5/13/64			6.5
995-000-066	NOT TITLED	4/12/64	5/27/64			6.5
995-000-067	NOT TITLED	4/26/64	6/10/64			6.5
995-000-070	NOT TITLED	5/10/64	6/24/64			6.5
995-000-071	NOT TITLED	5/24/64	7/08/64	7/01/64		6.5
995-000-036	NOT TITLED	8/03/63	9/18/63			6.6
995-000-033	NOT TITLED	8/24/63	10/09/63			6.6
995-000-034	NOT TITLED	8/31/63	10/16/63	10/01/63		6.6
995-000-040	NOT TITLED	8/31/63	10/16/63			6.6
995-000-035	NOT TITLED	9/14/63	10/30/63			6.6
995-000-037	NOT TITLED	9/21/63	11/06/63			6.6
995-000-044	NOT TITLED	9/28/63	11/13/63			6.6
995-000-038	NOT TITLED	9/28/63	11/13/63			6.6
995-000-039	NOT TITLED	10/12/63	11/27/63			6.6
995-000-041	NOT TITLED	10/19/63	12/04/63			6.6
995-000-042	NOT TITLED	10/26/63	12/11/63			6.6
995-000-048	NOT TITLED	10/26/63	12/11/63			6.6
995-000-043	NOT TITLED	11/09/63	12/25/63			6.6
995-000-045	NOT TITLED	11/16/63	1/01/64			6.6
995-000-046	NOT TITLED	11/23/63	1/08/64			6.6
995-000-052	NOT TITLED	11/23/63	1/08/64			6.6
995-000-047	NOT TITLED	12/07/63	1/22/64			6.6
995-000-049	NOT TITLED	12/14/63	1/29/64			6.6

CONFIDENTIAL

Figure 8a

CONFIDENTIAL

SMS SYSTEM

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-050	NOT TITLED	12/21/63	2/05/64			6.6
995-000-056	NOT TITLED	12/21/63	2/05/64			6.6
995-000-051	NOT TITLED	1/04/64	2/19/64			6.6
995-000-053	NOT TITLED	1/11/64	2/26/64			6.6
995-000-054	NOT TITLED	1/18/64	3/04/64			6.6
995-000-055	NOT TITLED	2/01/64	3/18/64			6.6
995-000-087	NOT TITLED	2/01/64	3/18/64			6.6
995-000-057	NOT TITLED	2/08/64	3/25/64			6.6
995-000-058	NOT TITLED	2/15/64	4/01/64			6.6
995-000-064	NOT TITLED	2/15/64	4/01/64			6.6
995-000-059	NOT TITLED	2/29/64	4/15/64			6.6
995-000-068	NOT TITLED	3/14/64	4/29/64			6.6
995-000-065	NOT TITLED	4/04/64	5/20/64			6.6
995-000-069	NOT TITLED	5/02/64	6/17/64			6.6
995-000-021	NOT TITLED	1/05/63	2/23/63			7.0
995-000-022	NOT TITLED	3/02/63	4/20/63			7.0
995-000-023	NOT TITLED	4/27/63	6/15/63	6/15/63		7.0
995-000-877	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 3	5/02/64	6/24/64			7.6
995-000-953	NOT TITLED	11/09/63	1/12/64			9.1
995-000-852	ESCAPE PROP DEL NO 39	5/08/65	7/11/65			9.1
995-000-878	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 4	5/16/64	7/25/64			10.0
995-000-836	ESCAPE PROP DEL NO 23	9/12/64	11/25/64			10.6
995-000-879	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 5	5/30/64	8/19/64			11.6
995-000-886	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 12	9/05/64	11/25/64			11.6
995-000-902	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 28	4/17/65	7/11/65			12.1

CONFIDENTIAL

Figure 8a

CONFIDENTIAL

SMS SYSTEM

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-828	ESCAPE PROP DEL NO 15	5/23/64	8/19/64			12.6
995-000-826	ESCAPE PROP DEL NO 13	4/25/64	7/25/64			13.0
995-000-013	NOT TITLED	12/08/62	3/21/63			14.8
995-000-018	NOT TITLED	12/08/62	3/21/63			14.8
995-000-014	NOT TITLED	2/02/63	5/16/63	2/01/63		14.8
995-000-024	NOT TITLED	2/02/63	5/16/63			14.8
995-000-019	NOT TITLED	2/02/63	5/16/63			14.8
995-000-025	NOT TITLED	3/30/63	7/11/63			14.8
995-000-020	NOT TITLED	3/30/63	7/11/63	5/01/63		14.8
995-000-026	NOT TITLED	5/25/63	9/05/63	8/01/63		14.8
995-000-029	NOT TITLED	7/20/63	10/31/63	11/01/63		14.8
995-000-169	NOT TITLED	6/19/65	9/30/65			14.8
995-000-170	NOT TITLED	10/23/65	2/03/66			14.8
995-000-171	NOT TITLED	12/18/65	3/31/66	4/01/66		14.8
995-000-181	NOT TITLED	8/14/65	12/01/65			15.6
995-000-182	NOT TITLED	12/18/65	4/06/66			15.6
995-000-183	NOT TITLED	2/12/66	6/01/66	6/01/66		15.6
995-000-175	NOT TITLED	7/17/65	11/09/65			16.4
995-000-184	NOT TITLED	8/28/65	12/21/65			16.4
995-000-176	NOT TITLED	11/20/65	3/15/66			16.4
995-000-185	NOT TITLED	1/01/66	4/26/66			16.4
995-000-177	NOT TITLED	1/15/66	5/10/66	12/01/65		16.4
995-000-186	NOT TITLED	2/26/66	6/21/66	2/01/66		16.4
995-000-192	NOT TITLED	4/09/66	8/02/66	3/01/66		16.4
995-000-198	NOT TITLED	5/21/66	9/13/66	5/01/66		16.4

[redacted]

Figure 8a

CONFIDENTIAL

SMS S Y S T E M

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-204	NOT TITLED	7/02/66	10/25/66	6/15/66		16.4
995-000-207	NOT TITLED	7/30/66	11/22/66	3/07/67		16.4
995-000-213	NOT TITLED	10/22/66	2/14/67	4/25/67		16.4
995-000-219	NOT TITLED	1/14/67	5/09/67	6/13/67		16.4
995-000-225	NOT TITLED	4/08/67	8/01/67	8/01/67		16.4
995-000-822	ESCAPE PROP DEL NO 9	2/29/64	6/24/64			16.6
995-000-824	ESCAPE PROP DEL NO 11	3/28/64	7/22/64			16.6
995-000-861	ESCAPE PROP DEL NO 48	1/11/64	5/11/64			17.3
995-000-157	NOT TITLED	4/24/65	8/31/65			18.4
995-000-163	NOT TITLED	5/22/65	9/28/65			18.4
995-000-158	NOT TITLED	8/28/65	1/04/66			18.4
995-000-164	NOT TITLED	9/25/65	2/01/66			18.4
995-000-190	NOT TITLED	9/25/65	2/01/66			18.4
995-000-159	NOT TITLED	10/23/65	3/01/66	3/01/66		18.4
995-000-165	NOT TITLED	11/20/65	3/29/66	11/01/65		18.4
995-000-191	NOT TITLED	1/29/66	6/07/66			18.4
995-000-027	NOT TITLED	3/02/63	7/11/63			18.8
995-000-028	NOT TITLED	4/27/63	9/05/63			18.8
995-000-911	LUNAR LDG PROP SPEC APPROVAL	1/27/62	6/10/62			19.1
995-000-912	LUNAR LDG PROP PRELIM MOCKUP	9/01/62	1/13/63			19.1
995-000-913	LUNAR LDG PROP PRELIM ENGR RELEASE	9/29/62	2/10/63			19.1
995-000-949	LUNAR LDG PROP FINAL MOCKUP	5/04/63	9/15/63			19.1
995-000-950	LUNAR LDG PROP FINAL ENGR RELEASE	6/01/63	10/13/63			19.1
995-000-951	LUNAR LDG PROP DELIVERY NO 1	11/09/63	3/22/64			19.1
995-000-940	LUNAR LDG PROP DELIVERY NO 18	2/27/65	7/11/65			19.1

CONFIDENTIAL

Figure 8a

CONFIDENTIAL

SMS SYSTEM

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-187	NOT TITLED	9/11/65	1/27/66			19.8
995-000-193	NOT TITLED	10/09/65	2/24/66			19.8
995-000-188	NOT TITLED	1/15/66	6/02/66			19.8
995-000-194	NOT TITLED	2/12/66	6/30/66			19.8
995-000-189	NOT TITLED	3/12/66	7/28/66	7/29/66		19.8
995-000-195	NOT TITLED	4/09/66	8/25/66	8/26/66		19.8
995-000-818	ESCAPE PROP DEL NO 5	1/04/64	5/25/64			20.3
995-000-196	NOT TITLED	10/23/65	3/15/66			20.4
995-000-205	NOT TITLED	1/01/66	5/24/66			20.4
995-000-197	NOT TITLED	2/26/66	7/19/66			20.4
995-000-211	NOT TITLED	3/26/66	8/16/66			20.4
995-000-206	NOT TITLED	5/07/66	9/27/66			20.4
995-000-217	NOT TITLED	6/18/66	11/08/66			20.4
995-000-212	NOT TITLED	7/30/66	12/20/66			20.4
995-000-223	NOT TITLED	9/10/66	1/31/67			20.4
995-000-218	NOT TITLED	10/22/66	3/14/67			20.4
995-000-224	NOT TITLED	1/14/67	6/06/67			20.4
995-000-820	ESCAPE PROP DEL NO 7	2/01/64	6/24/64			20.6
995-000-931	LUNAR LDG PROP DELIVERY NO 9	6/20/64	11/11/64			20.6
995-000-166	NOT TITLED	6/05/65	11/04/65			21.8
995-000-172	NOT TITLED	7/03/65	12/02/65			21.8
995-000-178	NOT TITLED	7/31/65	12/30/65			21.8
995-000-167	NOT TITLED	10/09/65	3/10/66			21.8
995-000-173	NOT TITLED	11/06/65	4/07/66			21.8
995-000-168	NOT TITLED	12/04/65	5/05/66	3/11/66		21.8

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-179	NOT TITLED	12/04/65	5/05/66			21.8
995-000-174	NOT TITLED	1/01/66	6/02/66	5/06/66		21.8
995-000-180	NOT TITLED	1/29/66	6/30/66	7/01/66		21.8
995-000-220	NOT TITLED	7/30/66	12/31/66			22.0
995-000-221	NOT TITLED	12/03/66	5/06/67			22.0
995-000-222	NOT TITLED	1/28/67	7/01/67	7/01/67		22.0
995-000-202	NOT TITLED	11/20/65	4/26/66			22.4
995-000-203	NOT TITLED	3/26/66	8/30/66			22.4
995-000-862	ESCAPE PROP DEL NO 49	2/01/64	7/11/64			23.0
995-000-139	NOT TITLED	1/30/65	7/15/65			23.8
995-000-140	NOT TITLED	6/05/65	11/18/65			23.8
995-000-132	NOT TITLED	7/03/65	12/16/65	9/23/65		23.8
995-000-141	NOT TITLED	7/31/65	1/13/66	10/21/65		23.8
995-000-144	NOT TITLED	8/28/65	2/10/66	12/16/65		23.8
995-000-150	NOT TITLED	9/25/65	3/10/66	1/14/66		23.8
995-000-156	NOT TITLED	10/23/65	4/07/66	2/11/66		23.8
995-000-214	NOT TITLED	5/07/66	10/31/66			25.3
995-000-215	NOT TITLED	9/10/66	3/06/67			25.3
995-000-216	NOT TITLED	11/05/66	5/01/67	5/01/67		25.3
995-000-846	ESCAPE PROP DEL NO 33	2/13/65	8/11/65			25.6
995-000-130	NOT TITLED	12/19/64	6/17/65			25.8
995-000-142	NOT TITLED	2/13/65	8/12/65			25.8
995-000-148	NOT TITLED	3/13/65	9/09/65			25.8
995-000-154	NOT TITLED	4/10/65	10/07/65			25.8
995-000-131	NOT TITLED	4/24/65	10/21/65			25.8

CONFIDENTIAL

Figure 8a

CONFIDENTIAL

SMS S Y S T E M

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-143	NOT TITLED	6/19/65	12/16/65			25.8
995-000-149	NOT TITLED	7/17/65	1/13/66			25.8
995-000-155	NOT TITLED	8/14/65	2/10/66			25.8
995-000-133	NOT TITLED	1/02/65	7/06/65			26.4
995-000-844	ESCAPE PROP DEL NO 31	1/16/65	7/20/65			26.4
995-000-847	ESCAPE PROP DEL NO 34	2/27/65	8/31/65			26.4
995-000-134	NOT TITLED	5/08/65	11/09/65			26.4
995-000-135	NOT TITLED	7/03/65	1/04/66	8/01/65		26.4
995-000-854	ESCAPE PROP DEL NO 41	7/03/65	1/04/66			26.4
995-000-138	NOT TITLED	8/14/65	2/15/66	9/01/65		26.4
995-000-856	ESCAPE PROP DEL NO 43	9/25/65	3/29/66			26.4
995-000-858	ESCAPE PROP DEL NO 45	12/18/65	6/21/66			26.4
995-000-860	ESCAPE PROP DEL NO 47	3/12/66	9/13/66			26.4
995-000-842	ESCAPE PROP DEL NO 29	12/05/64	6/10/65			26.8
995-000-892	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 18	11/28/64	6/10/65			27.8
995-000-859	ESCAPE PROP DEL NO 46	1/29/66	8/13/66			28.0
995-000-849	ESCAPE PROP DEL NO 36	3/27/65	10/12/65			28.4
995-000-896	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 22	1/23/65	8/11/65			28.6
995-000-894	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 20	12/26/64	7/20/65			29.4
995-000-897	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 23	2/06/65	8/31/65			29.4
995-000-904	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 30	7/10/65	2/01/66			29.4
995-000-906	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 32	10/02/65	4/26/66			29.4
995-000-908	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 34	12/25/65	7/19/66			29.4
995-000-841	ESCAPE PROP DEL NO 28	11/21/64	6/17/65			29.8
995-000-848	ESCAPE PROP DEL NO 35	3/13/65	10/07/65			29.8

CONFIDENTIAL

Figure 8a

CONFIDENTIAL

SMS SYSTEM

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-850	ESCAPE PROP DEL NO 37	4/10/65	11/04/65			29.8
995-000-838	ESCAPE PROP DEL NO 25	10/10/64	5/11/65			30.4
995-000-840	ESCAPE PROP DEL NO 27	11/07/64	6/08/65			30.4
995-000-136	NOT TITLED	1/16/65	8/17/65			30.4
995-000-851	ESCAPE PROP DEL NO 38	4/24/65	11/23/65			30.4
995-000-137	NOT TITLED	5/22/65	12/21/65			30.4
995-000-909	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 35	2/05/66	9/10/66			31.0
995-000-857	ESCAPE PROP DEL NO 44	11/06/65	6/13/66			31.3
995-000-888	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 14	10/03/64	5/11/65			31.4
995-000-890	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 16	10/31/64	6/08/65			31.4
995-000-899	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 25	3/06/65	10/12/65			31.4
995-000-903	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 29	5/29/65	1/04/66			31.4
995-000-910	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 36	3/05/66	10/11/66			31.4
995-000-843	ESCAPE PROP DEL NO 30	1/02/65	8/12/65			31.8
995-000-845	ESCAPE PROP DEL NO 32	1/30/65	9/09/65			31.8
995-000-853	ESCAPE PROP DEL NO 40	5/22/65	1/04/66			32.4
995-000-941	LUNAR LDG PROP DELIVERY NO 19	5/22/65	1/04/66			32.4
995-000-942	LUNAR LDG PROP DELIVERY NO 20	6/19/65	2/01/66			32.4
995-000-898	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 24	2/20/65	10/07/65			32.8
995-000-900	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 26	3/20/65	11/04/65			32.8
995-000-208	NOT TITLED	2/12/66	10/01/66			33.0
995-000-209	NOT TITLED	6/18/66	2/04/67			33.0
995-000-210	NOT TITLED	8/13/66	4/01/67	4/01/67		33.0
995-000-901	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 27	4/03/65	11/23/65			33.4
995-000-907	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 33	11/13/65	7/11/66			34.3

[redacted]

[redacted]

SMS SYSTEM

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-932	LUNAR LDG PROP DELIVERY NO 10	7/18/64	3/16/65			34.4
995-000-891	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 17	11/14/64	7/15/65			34.8
995-000-893	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 19	12/12/64	8/12/65			34.8
995-000-895	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 21	1/09/65	9/09/65			34.8
995-000-832	ESCAPE PROP DEL NO 19	7/18/64	3/25/65			35.8
995-000-933	LUNAR LDG PROP DELIVERY NO 11	8/15/64	4/27/65			36.4
995-000-944	LUNAR LDG PROP DELIVERY NO 22	8/14/65	4/26/66			36.4
995-000-816	ESCAPE PROP DEL NO 3	12/07/63	8/19/64			36.6
995-000-882	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 8	7/11/64	3/25/65			36.8
995-000-829	ESCAPE PROP DEL NO 16	6/06/64	2/25/65			37.8
995-000-833	ESCAPE PROP DEL NO 20	8/01/64	4/22/65			37.8
995-000-835	ESCAPE PROP DEL NO 22	8/29/64	5/20/65			37.8
995-000-837	ESCAPE PROP DEL NO 24	9/26/64	6/17/65			37.8
995-000-830	ESCAPE PROP DEL NO 17	6/20/64	3/16/65			38.4
995-000-934	LUNAR LDG PROP DELIVERY NO 12	9/12/64	6/08/65			38.4
995-000-937	LUNAR LDG PROP DELIVERY NO 15	12/05/64	8/31/65			38.4
995-000-883	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 9	7/25/64	4/22/65			38.8
995-000-885	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 11	8/22/64	5/20/65			38.8
995-000-887	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 13	9/19/64	6/17/65			38.8
995-000-855	ESCAPE PROP DEL NO 42	8/14/65	5/14/66			39.0
995-000-880	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 6	6/13/64	3/16/65			39.4
995-000-936	LUNAR LDG PROP DELIVERY NO 14	11/07/64	8/11/65			39.6
995-000-935	LUNAR LDG PROP DELIVERY NO 13	10/10/64	7/20/65			40.4
995-000-938	LUNAR LDG PROP DELIVERY NO 16	1/02/65	10/12/65			40.4
995-000-946	LUNAR LDG PROP DELIVERY NO 24	10/09/65	7/19/66			40.4

[redacted]

CONFIDENTIAL

SMS SYSTEM

DATE 6/07/61 WEEK 127.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-000-905	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 31	8/21/65	6/11/66			42.0
995-000-831	ESCAPE PROP DEL NO 18	7/04/64	4/27/65			42.4
995-000-939	LUNAR LDG PROP DELIVERY NO 17	1/30/65	11/23/65			42.4
995-000-945	LUNAR LDG PROP DELIVERY NO 23	9/11/65	7/11/66			43.3
995-000-881	MIDCOURSE & LUNAR TAKEOFF PROP DEL NO 7	6/27/64	4/27/65			43.4
995-000-947	LUNAR LDG PROP DELIVERY NO 25	11/06/65	9/10/66			44.0
995-000-948	LUNAR LDG PROP DELIVERY NO 26	12/04/65	10/11/66			44.4
995-000-943	LUNAR LDG PROP DELIVERY NO 21	7/17/65	6/11/66			47.0

CONFIDENTIAL

Figure 8a

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-300-000	PROJECT GO-AHEAD	0/00/00	0/00/00			0.4
995-300-001	INITIATE SPECIFICATION DEVELOPMENT	7/01/61	7/04/61			0.4
995-300-002	SPECIFICATIONS APPROVED	7/29/61	8/01/61			0.4
995-300-003	CONTRACTOR SELECTED	9/23/61	9/26/61			0.4
995-300-005	CAPSULE AVAILABLE C11	1/13/62	1/16/62			0.4
995-300-004	COMPLETE ENGINEERING DESIGN	1/13/62	1/16/62			0.4
995-300-006	CAPSULE MODIFIED C11	7/14/62	7/17/62			0.4
995-300-007	CST & ENVIRON TEST C11	9/08/62	9/11/62			0.4
995-300-008	FIRST MATE C11	12/01/62	12/04/62			0.4
995-300-009	LAUNCH C11	12/29/62	1/01/63	1/01/63		0.4
995-300-013	CAPSULE AVAILABLE C13	2/24/62	3/15/62			2.8
995-300-014	CAPSULE MODIFIELD C13	8/25/62	9/13/62			2.8
995-300-015	CST C13	10/20/62	11/08/62			2.8
995-300-016	FIRST MATE C13	1/12/63	1/31/63			2.8
995-300-017	LAUNCH C13	2/09/63	2/28/63	3/01/63		2.8
995-300-018	CAPSULE AVAILABLE C15	4/07/62	5/16/62			5.6
995-300-019	CAPSULE MODIFIED C15	10/06/62	11/14/62			5.6
995-300-020	CST C15	12/01/62	1/09/63			5.6
995-300-021	FIRST MATE C15	2/23/63	4/03/63			5.6
995-300-022	LAUNCH C15	3/23/63	5/01/63	5/01/63		5.6
995-300-023	CAPSULE AVAILABLE C16	5/19/62	7/16/62			8.3
995-300-024	CAPSULE MODIFIED C16	11/17/62	1/14/63			8.3
995-300-025	CST C16	1/12/63	3/11/63			8.3
995-300-026	FIRST MATE C16	4/06/63	6/03/63			8.3
995-300-027	LAUNCH C16	5/04/63	7/01/63	7/01/63		8.3

CONFIDENTIAL

Figure 8b

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-300-815	EXPER EQUIP PACKAGE 1 DEL	7/14/62	9/11/62			8.4
995-300-820	START PAYLOAD ASSEMBLY 1	10/27/62	12/25/62			8.4
995-300-843	EXPER EQUIP PACKAGE 2 DEL	8/25/62	11/08/62			10.8
995-300-840	START PAYLOAD ASSEMBLY 2	12/08/62	2/21/63			10.8
995-300-838	EXPER EQUIP PACKAGE 3 DEL	10/06/62	1/09/63			13.6
995-300-834	START PAYLOAD ASSEMBLY 3	1/19/63	4/24/63			13.6
995-300-828	EXPER EQUIP PACKAGE 4 DEL	11/17/62	3/11/63			16.3
995-300-830	START PAYLOAD ASSEMBLY 4	3/02/63	6/24/63			16.3
995-300-812	EXP MOCKUP DEL TO TRAINING SITE	1/27/62	6/07/62	2/01/62		18.8
995-300-813	SELECT PRIMATES 1	6/16/62	10/25/62			18.8
995-300-821	SELECT PRIMATES 2	9/08/62	1/17/63			18.8
995-300-839	MAMMALS DEL TO CC 2	9/15/62	1/24/63			18.8
995-300-814	EXP PACKAGE COMPLETE	3/31/62	8/14/62	4/01/62		19.4
995-300-822	SELECT PRIMATES 3	11/03/62	3/20/63			19.6
995-300-833	MAMMALS DEL TO CC 3	11/10/62	3/27/63			19.6
995-300-823	SELECT PRIMATES 4	12/29/62	5/20/63			20.3
995-300-827	MAMMALS DEL TO CC 4	1/05/63	5/27/63			20.3
995-300-817	MAMMALS DEL TO CC 1	6/23/62	11/27/62			22.4
995-300-802	EXPERIMENTAL DESIGN COMPLETE	7/29/61	1/11/62			23.8
995-300-805	ORDER RODENTS	8/12/61	1/25/62			23.8
995-300-806	START BREEDING RODENTS	8/19/61	2/01/62			23.8
995-300-807	RODENTS AVAILABLE	10/28/61	4/12/62			23.8
995-300-808	START TRAINING RODENTS	2/17/62	8/02/62			23.8
995-300-816	SELECT RODENTS 1	5/12/62	10/25/62			23.8
995-300-824	SELECT RODENTS 2	8/04/62	1/17/63			23.8

CONFIDENTIAL

Figure 8b

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-300-825	SELECT RODENTS 3	9/29/62	3/20/63			24.6
995-300-826	SELECT RODENTS 4	11/24/62	5/20/63			25.3
995-300-803	START LAB FURNISHING	7/01/61	1/04/62			26.8
995-300-804	ORDER BIOLOGICAL SPECIMENS	8/12/61	4/17/62			35.4
995-300-809	START GROWTH AND STANDARDIZATION	9/09/61	5/15/62			35.4
995-300-810	SELECT BIOLOGICAL FLIGHT SPECIMENS	4/07/62	12/11/62			35.4
995-300-819	BIOLOGICAL FLIGHT SPECIMENS DEL 1	4/14/62	12/18/62			35.4
995-300-811	START PRIMATE TRAIN COND AND BASELINE	8/12/61	4/19/62			35.8
995-300-844	BIOLOGICAL FLIGHT SPECIMENS DEL 2	6/09/62	2/14/63			35.8
995-300-845	BIOLOGICAL FLIGHT SPECIMENS DEL 3	8/04/62	4/17/63			36.6
995-300-829	BIOLOGICAL FLIGHT SPECIMENS DEL 4	9/29/62	6/17/63			37.3

CONFIDENTIAL

Figure 8b

CONFIDENTIAL

SMS SYSTEM

DATE 6/02/61 WEEK 126.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-400-000	PROJECT GO - AHEAD	0/00/00	0/00/00			- 2.2
995-400-001	INITIATE PREPARATION OF SPECIFICATIONS	7/01/61	6/15/61	7/01/61		- 2.2
995-400-002	SPECIFICATION APPROVAL	8/05/61	7/20/61			- 2.2
995-400-003	SELECT CONTRACTOR	10/14/61	9/28/61			- 2.2
995-400-026	SELECT SUB-CONTRACTORS	10/28/61	10/12/61			- 2.2
995-400-004	PRELIM ENGINEERING RELEASE	12/09/61	11/23/61			- 2.2
995-400-027	SUB-SYSTEMS DESIGN & MOCK UP	12/09/61	11/23/61			- 2.2
995-400-006	MOCK UP	1/06/62	12/21/61			- 2.2
995-400-007	FINAL ENGINEERING RELEASE	2/17/62	2/01/62			- 2.2
995-400-028	ALL SUB-SYSTEMS DELIVERED	7/21/62	7/05/62			- 2.2
995-400-008	DELIVER S/C 1	9/15/62	8/30/62			- 2.2
995-400-012	DELIVER SPARE S/C	10/20/62	10/04/62			- 2.2
995-400-014	DELIVER S/C 2	11/24/62	11/08/62			- 2.2
995-400-015	COMPLETE ENVIRON TEST S/C 2	1/19/63	1/03/63			- 2.2
995-400-016	FIRST MATE S/C 2	2/16/63	1/31/63			- 2.2
995-400-017	LAUNCH S/C 2	3/16/63	2/28/63	3/01/63		- 2.2
995-400-009	COMPLETE ENVIRONMENTAL TEST S/C 1	11/10/62	11/06/62			- 0.6
995-400-010	FIRST MATE S/C 1	12/08/62	12/04/62			- 0.6
995-400-013	COMPLETE ENVIRON TEST SPARE S/C	12/15/62	12/11/62	12/11/62		- 0.6
995-400-011	LAUNCH S/C 1	1/05/63	1/01/63	1/01/63		- 0.6
995-400-018	DELIVER S/C 3	12/29/62	1/09/63			1.6
995-400-019	COMPLETE ENVIRON TEST S/C 3	2/23/63	3/06/63			1.6
995-400-020	FIRST MATE S/C 3	3/23/63	4/03/63			1.6
995-400-021	LAUNCH S/C 3	4/20/63	5/01/63	5/01/63		1.6
995-400-005	INSTRUMENTATION SPECIFIED	3/03/62	3/15/62			1.8

CONFIDENTIAL

CONFIDENTIAL

SYSTEM

DATE 6/02/61 WEEK 126.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-400-022	DELIVER S/C 4	2/02/63	3/11/63			5.3
995-400-023	COMPLETE ENVIRON TEST S/C 4	3/30/63	5/06/63			5.3
995-400-024	FIRST MATE S/C 4	4/27/63	6/03/63			5.3
995-400-025	LAUNCH S/C 4	5/25/63	7/01/63	7/01/63		5.3

CONFIDENTIAL

Figure 8c

CONFIDENTIAL

SMS SYSTEM

DATE 6/09/61 WEEK 127.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-500-000	START	0/00/00	0/00/00			4.4
995-500-001	INITIATE SPECIFICATION PREPARATION	7/01/61	8/01/61	7/01/61		4.4
995-500-002	SPECIFICATION APPROVAL	8/05/61	9/05/61			4.4
995-500-003	SELECT CONTRACTOR	10/14/61	11/14/61			4.4
995-500-004	PRELIMINARY ENGINEERING RELEASE	12/09/61	1/09/62			4.4
995-500-006	MOCKUP	1/06/62	2/06/62			4.4
995-500-007	FINAL ENGINEERING RELEASE	2/17/62	3/20/62			4.4
995-500-011	DELIVER SPACECRAFT 1	10/27/62	11/27/62			4.4
995-500-015	DELIVER SPARE SPACECRAFT 1	12/01/62	1/01/63			4.4
995-500-017	DELIVER SPACECRAFT 2	1/05/63	2/05/63			4.4
995-500-021	DELIVER SPARE SPACECRAFT 2	2/09/63	3/12/63			4.4
995-500-023	DELIVER SPACECRAFT 3	3/16/63	4/16/63			4.4
995-500-833	DEL EXPER EQUIP PKG 3 TO CC	3/16/63	4/16/63			4.4
995-500-027	DELIVER SPACECRAFT 4	4/20/63	5/21/63			4.4
995-500-832	DEL EXPER EQUIP PKG 4 TO CC	5/11/63	6/11/63			4.4
995-500-028	ENVIRONMENTAL TEST SPACECRAFT 4	6/15/63	7/16/63			4.4
995-500-029	FIRST MATE SPACECRAFT 4	8/03/63	9/03/63			4.4
995-500-851	START PAYLOAD ASSEMBLY 4	8/24/63	9/24/63			4.4
995-500-030	LAUNCH SPACECRAFT 4 ON CENTAUR	8/31/63	10/01/63	10/01/63		4.4
995-500-857	INSERT PAYLOAD 4	8/31/63	10/01/63			4.4
995-500-012	COMPLETE ENVIRONMENTAL TEST SC 1	12/22/62	1/23/63			4.6
995-500-013	FIRST MATE SC 1	3/02/63	4/03/63			4.6
995-500-014	LAUNCH SC 1 ON ATLAS AGENA	3/30/63	5/01/63	5/01/63		4.6
995-500-022	ENVIRONMENTAL TEST SPARE SPACECRAFT 2	4/06/63	5/12/63	5/12/63		5.1
995-500-024	ENVIRONMENTAL TEST SPACECRAFT 3	5/11/63	6/15/63			5.1

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/09/61 WEEK 127.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-500-025	FIRST MATE SPACECRAFT 3	6/29/63	8/04/63			5.1
995-500-026	LAUNCH SPACECRAFT 3 ON CENTAUR	7/27/63	9/01/63	9/01/63		5.1
995-500-016	ENVIRONMENTAL TEST SPARE SPACECRAFT 1	1/26/63	3/07/63	3/07/63		5.7
995-500-018	ENVIRONMENTAL TEST SPACECRAFT 2	3/02/63	4/15/63			6.3
995-500-019	FIRST MATE SPACECRAFT 2	4/20/63	6/03/63			6.3
995-500-020	LAUNCH SPACECRAFT 2 ON ATLAS AGENA	5/18/63	7/01/63	7/01/63		6.3
995-500-008	SELECT SUBCONTRACTORS	10/28/61	12/12/61			6.4
995-500-009	SUBSYSTEMS DESIGNED & MOCKED UP	12/09/61	1/23/62			6.4
995-500-834	DEL EXPER EQUIP PKG 2 TO CC	1/05/63	2/19/63			6.4
995-500-852	START PAYLOAD ASSEMBLY 3	6/29/63	8/24/63			8.1
995-500-858	INSERT PAYLOAD 3	7/06/63	9/01/63			8.1
995-500-835	DEL EXPER EQUIP PKG 1 TO CC	10/27/62	12/25/62			8.4
995-500-853	START PAYLOAD ASSEMBLY 2	4/20/63	6/24/63			9.3
995-500-859	INSERT PAYLOAD 2	4/27/63	7/01/63			9.3
995-500-831	DEL EXPER EQUIP PKG 5 TO CC	7/06/63	9/11/63			9.6
995-500-850	START PAYLOAD ASSEMBLY 5	10/19/63	12/25/63			9.6
995-500-034	LAUNCH SPACECRAFT 5 ON CENTAUR	10/26/63	1/01/64	1/01/64		9.6
995-500-856	INSERT PAYLOAD 5	10/26/63	1/01/64			9.6
995-500-830	DEL EXPER EQUIP PKG 6 TO CC	8/31/63	11/09/63			10.1
995-500-849	START PAYLOAD ASSEMBLY 6	12/14/63	2/22/64			10.1
995-500-038	LAUNCH SPACECRAFT 6 ON CENTAUR	12/21/63	3/01/64	3/01/64		10.1
995-500-855	INSERT PAYLOAD 6	12/21/63	3/01/64			10.1
995-500-010	ALL SUBSYSTEMS DELIVERED	7/21/62	10/02/62			10.4
995-500-854	START PAYLOAD ASSEMBLY 1	2/09/63	4/24/63			10.6
995-500-860	INSERT PAYLOAD 1	2/16/63	5/01/63			10.6

CONFIDENTIAL

Figure 8d

CONFIDENTIAL

SMS SYSTEM

DATE 6/09/61 WEEK 127.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-500-031	DELIVER SPACECRAFT 5	5/25/63	8/21/63			12.6
995-500-032	ENVIRONMENTAL TEST SPACECRAFT 5	7/20/63	10/16/63			12.6
995-500-033	FIRST MATE SPACECRAFT 5	9/07/63	12/04/63			12.6
995-500-005	INSTRUMENTATION SPECIFIED	3/03/62	6/12/62			14.4
995-500-035	DELIVER SPACECRAFT 6	6/29/63	10/19/63			16.1
995-500-036	ENVIRONMENTAL TEST SPACECRAFT 6	8/24/63	12/14/63			16.1
995-500-037	FIRST MATE SPACECRAFT 6	10/12/63	2/02/64			16.1
995-500-802	CENTRAL BIO SOURCES ESTABLISHED	9/09/61	1/02/62			16.4
995-500-812	START GROWTH AND STANDARDIZATION	12/02/61	3/27/62			16.4
995-500-813	SELECT MICRO BIO COMPONENTS	12/01/62	3/26/63			16.4
995-500-848	MICRO BIO COMPONENTS DEL TO CC 1	12/08/62	4/02/63			16.4
995-500-847	MICRO BIO COMPONENTS DEL TO CC 2	2/02/63	5/28/63			16.4
995-500-846	MICRO BIO COMPONENTS DEL TO CC 3	3/30/63	7/23/63			16.4
995-500-845	MICRO BIO COMPONENTS DEL TO CC 4	5/25/63	9/17/63			16.4
995-500-816	START CONTROL STUDIES FOR 1 FLIGHT	12/08/62	4/17/63			18.6
995-500-806	SUB SYSTEM DESIGNED AND MOCKUP	10/28/61	3/20/62			20.4
995-500-823	EXP PACKAGE COMPLETE	6/09/62	10/30/62			20.4
995-500-844	MICRO BIO COMPONENTS DEL TO CC 5	7/20/63	12/18/63			21.6
995-500-843	MICRO BIO COMPONENTS DEL TO CC 6	9/14/63	2/15/64			22.1
995-500-803	START CONSTRUCTION OF HOLDING EQUIPMENT	9/23/61	3/06/62			23.4
995-500-807	START BREEDING RODENTS	10/21/61	4/03/62			23.4
995-500-809	RODENTS AVAILABLE	3/10/62	8/21/62			23.4
995-500-814	START TRAINING RODENTS	6/30/62	12/11/62			23.4
995-500-822	SELECT RODENTS 1	9/22/62	3/05/63			23.4
995-500-821	SELECT RODENTS 2	11/17/62	4/30/63			23.4

CONFIDENTIAL

Figure 8d

CONFIDENTIAL

SMS SYSTEM

DATE 6/09/61 WEEK 127.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-500-820	SELECT RODENTS 3	1/12/63	6/25/63			23.4
995-500-819	SELECT RODENTS 4	3/09/63	8/20/63			23.4
995-500-839	MAMMALS DEL TO CC 4	3/16/63	8/27/63			23.4
995-500-842	MAMMALS DEL TO CC 1	9/29/62	3/27/63			25.6
995-500-841	MAMMALS DEL TO CC 2	11/24/62	5/27/63			26.3
995-500-840	MAMMALS DEL TO CC 3	1/19/63	7/27/63			27.1
995-500-804	ORDER RODENTS	9/09/61	3/27/62			28.4
995-500-808	EXP MOCKUP COMPLETE	3/03/62	9/18/62			28.4
995-500-811	EXP MOCKUP DEL TO TRAINING SITE	3/31/62	10/16/62			28.4
995-500-829	SELECT PRIMATES 1	8/18/62	3/05/63			28.4
995-500-828	SELECT PRIMATES 2	10/13/62	4/30/63			28.4
995-500-827	SELECT PRIMATES 3	12/08/62	6/25/63			28.4
995-500-826	SELECT PRIMATES 4	2/02/63	8/20/63			28.4
995-500-818	SELECT RODENTS 5	5/04/63	11/20/63			28.6
995-500-838	MAMMALS DEL TO CC 5	5/11/63	11/27/63			28.6
995-500-817	SELECT RODENTS 6	6/29/63	1/18/64			29.1
995-500-837	MAMMALS DEL TO CC 6	7/06/63	1/25/64			29.1
995-500-825	SELECT PRIMATES 5	3/30/63	11/20/63			33.6
995-500-824	SELECT PRIMATES 6	5/25/63	1/18/64			34.1
995-500-836	TRAINGING EQUIP DEL TO CC	5/26/62	1/30/63			35.6
995-500-805	PRIMATES DEL TO HOLLOMAN	9/09/61	6/19/62			40.4
995-500-810	PRIMATES STABILIZED	11/04/61	8/14/62			40.4
995-500-815	START PRIMATE TRAIN AND COND AND BASELINE	11/18/61	8/28/62			40.4

CONFIDENTIAL

Figure 8d

CONFIDENTIAL

SMS SYSTEM

DATE 6/02/61 WEEK 126.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-700-000	START APRIL 22 1961	0/00/00	0/00/00			8.0
995-700-001	REQUEST MAC PROPOSAL	7/01/61	8/26/61			8.0
995-700-002	ORDER SPACECRAFT C21-26	7/29/61	9/23/61			8.0
995-700-003	COMPLETE ENGINEERING DESIGN	8/26/61	10/21/61			8.0
995-700-004	DELIVER MAC CAPSULE 21	7/14/62	9/08/62			8.0
995-700-008	DELIVER MAC CAPSULE 22	8/25/62	10/20/62			8.0
995-700-012	DELIVER CAPSULE 23	10/06/62	12/01/62			8.0
995-700-013	CST CAPSULE 23	12/15/62	2/09/63			8.0
995-700-014	FIRST MATE CAPSULE 23	3/09/63	5/04/63			8.0
995-700-015	LAUNCH MA-17 C-23	4/06/63	6/01/63	6/01/63		8.0
995-700-018	DELIVER CAPSULE 24	11/17/62	1/31/63			10.7
995-700-019	CST CAPSULE 24	1/26/63	4/11/63			10.7
995-700-020	FIRST MATE CAPUSLE 24	4/20/63	7/04/63			10.7
995-700-021	LAUNCH MA-18 C-24	5/18/63	8/01/63	8/01/63		10.7
995-700-024	DELIVER CAPSULE 25	12/29/62	4/02/63			13.4
995-700-025	CST CAPSULE 25	3/09/63	6/11/63			13.4
995-700-026	FIRST MATE CAPSULE 25	6/01/63	9/03/63			13.4
995-700-027	LAUNCH MA-19 C-25	6/29/63	10/01/63	10/01/63		13.4
995-700-030	DELIVER CAPSULE 26	2/09/63	6/01/63			16.1
995-700-031	CST CAPSULE 26	4/20/63	8/10/63			16.1
995-700-032	FIRST MATE CAPSULE 26	7/13/63	11/03/63			16.1
995-700-033	LAUNCH MA-20 C-26	8/10/63	12/01/63	12/01/63		16.1
995-700-005	COMPLETE CST & ENV TESTS CAPSULE 21	9/22/62	2/16/63			21.0
995-700-006	FIRST MATE CAPSULE 21	12/15/62	5/11/63			21.0
995-700-007	LAUNCH MA-15 C-21	1/12/63	6/08/63	2/01/63		21.0

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/02/61 WEEK 126.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-700-034	RECYCLE CAPSULE 21	3/09/63	8/03/63			21.0
995-700-035	CST CAPSULE 21	5/18/63	10/12/63			21.0
995-700-036	FIRST MATE CAPSULE 21	8/10/63	1/04/64			21.0
995-700-037	LAUNCH MA-21 C-21	9/07/63	2/01/64	2/01/64		21.0
995-700-009	CST CAPSULE 22	11/03/62	4/17/63			23.6
995-700-010	FIRST MATE CAPSULE 21	1/26/63	7/10/63			23.6
995-700-011	LAUNCH MA-16 C-22	2/23/63	8/07/63	4/01/63		23.6
995-700-038	RECYCLE CAPSULE 22	4/20/63	10/02/63			23.6
995-700-039	CST CAPSULE 22 MA-22	6/29/63	12/11/63			23.6
995-700-040	FIRST MATE CAPSULE 22 MA-22	9/21/63	3/04/64			23.6
995-700-041	LAUNCH MA-22 C-22	10/19/63	4/01/64	4/01/64		23.6

CONFIDENTIAL

Figure 8e

CONFIDENTIAL

PART II

SECTION B

LAUNCH VEHICLE DEVELOPMENT PROGRAM

FOR

EARLY MANNED LUNAR LANDING

ELDON W. HALL - HQ, OLVP
MELVYN SAVAGE - HQ, OLVP
HEINZ H. KOELLE - MSFC
WILLIAM L. LOVEJOY - HQ, OLVP
NORMAN RAFEL - HQ, OLVP
ALFRED M. NELSON - HQ, OPPE

NASA

JUNE 16, 1961

CONFIDENTIAL

LAUNCH VEHICLES and SPACECRAFT PROPULSION

SUMMARY

In order to determine the feasibility and extent of the effort required to accomplish an early manned lunar landing, several typical Nova vehicles were selected to study the development schedule, actions required, decision points, costs, and performance. Both all-liquid and combinations of solid-liquid vehicles were considered.

Based on an estimated 12,500 pound capsule, the Nova vehicle must be capable of injecting 100-150,000 pounds into a 60 hr. transfer orbit depending on whether high-energy (H_2-O_2) or storable propellants, respectively, are used for the return propulsion. These estimates are somewhat higher than previous estimates primarily because the tight development schedule does not allow refinement of either the launch vehicle or the spacecraft in order to utilize the highest structural or trajectory efficiencies.

It was further determined that because there are still many unknown factors that might further increase payload requirements, the Nova vehicle should have a capability of 150,000 pounds to escape in order to accomplish the mission with storable propellant return. However, a vigorous development of the high-energy propulsion for return should be pursued because this constitutes the most expiditious method of obtaining a 50% increase in payload capability.

Because there are several intermediate missions prior to the manned lunar landing, some of which require a capability larger than the Saturn C-2, a C-3 vehicle should be developed instead of a C-2.

In order to avoid two completely independent liquid and solid vehicle designs it is desirable that the same or similar upper stages be used in both. It is also felt that the solid motors should provide backup capability to the F-1 so that success of the mission is not completely dependant on the F-1 engine. These factors provide another reason for use of hydrogen-oxygen propellants for the second stage of Nova, since stages using these propellants meet the requirements for either liquid or solid stages beneath.

The undertaking of parallel efforts in both all-liquid and solid-liquid C-3 and Nova will require first stage contract awards for all four first stages early in FY 1962 if all vehicles are to meet the schedules outlined in this report.

It appears that in the solid Nova development two solid stages

should be used where one stage using F-1 engines is used. While a single stage might be developed (providing three stages to escape velocity) problems regarding size, thrust level, burning time, and vehicle dynamics raise concern regarding its feasibility at this time. Its only advantage appears to be a reduction from 4 to 3 stages and the problems in the vehicle are reduced significantly by the addition of one more stage. By using two solid stages in Nova the second stage can become the first stage of C-3.

The major difference between the several liquid Novas considered was in the propulsion for the second stage. The propulsion considered was 2 F-1's, 8 J-2's, or 2 to 4 large H_2-O_2 engines of the 800 to 1000 K size.

The payload for the 2 F-1 second stage configuration was below that required for the Apollo 12,500 pound return capsule unless extremely light weight stages can be developed. Because of the tight development schedule, this configuration is considered to be a high risk approach from payload considerations, though most easily developed from the propulsion standpoint.

The 8 J-2 second stage approach provides adequate payload capability. However, the use of this many engines requires either extremely high single engine reliability or the development of an effective engine-out system which has not yet been accomplished.

The use of a cluster of 2 new 800 to 1000 K H_2-O_2 engines in the second stage in place of the 8 J-2's could ultimately provide increased stage reliability. Using 4 large H_2-O_2 engines in this stage could increase payload some 25%. Hence, the development of a new H_2-O_2 engine should be initiated immediately to assure vehicle growth potential and eventually a more reliable stage.

All vehicles considered of both C-3 and Nova type have one or more stages that use the J-2 engine. The J-2 development program, therefore, should be vigorously pushed to attain the maximum possible reliability from this engine.

Since the all-liquid C-3 and Nova vehicles are dependent on the F-1 and this engine is well under way, it is imperative that this development effort be vigorously pursued.

Performance differences between a cluster tank and a single tank for the first stage of Nova are believed sufficiently small (about 5-8%) so that selection of first stage tank arrangement should be based on manufacturing, handling and transporting, testing, reliability, and cost. Further investigation is necessary before a recommendation can be made. This decision, however, affects the test and launch

facilities to some extent and consequently must be made as soon as possible. Since contractor capability affects this decision, a contract for first stage design and construction should be initiated immediately.

BASIC ASSUMPTIONS

The purpose of this study was to investigate feasible launch vehicle configurations that can most rapidly be developed for the direct flight manned lunar landing and return. This study does not attempt to select the optimum vehicle configuration. Several configurations that could be developed on the most expeditious schedules were explored as regards schedules, costs, relative merits, and performance.

The basic assumptions used in this study are listed in Table B-I and explained more fully as follows:

1. The Nova vehicle must have sufficient payload to accomplish the manned lunar landing and return by direct flight without rendezvous and without the use of high-energy propellants in the lunar return propulsion system.

2. Development of a high-energy propellant propulsion system for the lunar return should be vigorously pursued to provide a significant increase in payload for later missions. This will be discussed in more detail later.

3. The configurations considered were limited to those that could most rapidly be developed to accomplish the manned lunar landing.

4. All payload estimates are to be based on stage weights, specific impulse, and flight propellant reserves consistent with an accelerated tight development schedule.

5. Nova vehicle development planning must include an all-liquid vehicle as well as a liquid-solid version. This means that both the F-1 and a large solid engine are to be used in the first stage or stages of Nova.

6. Payload capabilities for both all-liquid and solid-liquid Novas are to be similar.

7. A vehicle is required with payload capability between Saturn C-1 and Nova to satisfy payload requirements for manned spacecraft development, training flights, and space exploration required prior to the manned lunar landing. An all-liquid C-3 using the F-1 in the first stage and a solid-liquid vehicle using the large solid motor in the first stage are to be initiated.

8. Nuclear propulsion was not to be considered for the first landing but the vehicles should be consistent with later nuclear stages for later lunar exploration and more advanced missions.

9. Funding was based on the assumption that it was possible to use incremental funding for construction of facilities.

10. Development times were based on the use of a strong centralized program management organization and the assumption that the funding requirements for each fiscal year would be available on a timely basis.

MISSION REQUIREMENTS

The manned lunar landing mission will require a sizeable flight test program to develop the spacecraft, train the crews, conduct necessary life science experiments, and complete required unmanned deep space and lunar exploration.

The experiments concerned with radiation and space environments, biomedicine, multi-orbit manned and unmanned flights, training flights, and unmanned lunar exploration can be accomplished with existing vehicles (Argo, Thor-Delta, Little Joe, Atlas, Agena, Centaur, and aircraft).

Table B-II lists the major missions for which the Saturn and Nova type vehicles must be developed.

Saturn C-1: The 2-stage Saturn C-1 will be used to subject boiler-plate and prototype spacecraft to suborbital re-entry and orbital qualification, as well as to conduct lunar landing and take-off development tests.

Nova Primary Mission: The primary Nova payload requirement is that required to carry three men to the moon and return them to earth. A stay time of up to 24 hours on the moon was established as desirable.

The exact spacecraft weight can not be firmly established at this time. An assessment of the return capsule weight for the lunar landing and return (discussed in the spacecraft section) has indicated that 12,500 lbs. will be required to re-enter the earth's atmosphere at parabolic velocity. Nova must at least provide an escape payload consistent with this 12,500 lb. capsule weight.

Spacecraft Development Requirements: The development of the spacecraft and the crew training flights will require spacecraft parabolic re-entry, orbiting qualification tests, and manned elliptical and circumlunar flights.

The circumlunar escape payload requirement is of the order of 25,000 lbs. This is appreciably in excess of the 15 to 18,000 lb. escape payload capability of Saturn C-2. Therefore a vehicle of the Saturn C-3 size is required and this study will include the development of such a vehicle.

SPACECRAFT PROPULSION

The type of trajectory assumed for the mission is illustrated in figure B-1. Trajectories were assumed that result in parking orbits around both the earth and the moon. The use of low altitude parking orbits results in slight increases in velocity requirements, yet provides a much greater latitude in launch times both at the earth and at the moon on return.

Figure B-1 presents the velocity increments assumed, both the actual required and the calculated gravity losses for typical systems, for each of the maneuvers throughout the flight trajectory. These velocities and the necessary structure and propellant weights for landing and returning a 12,500 pound spacecraft are given in Table B-III for various phases of the trajectory.

For return with storable propellants (e.g. N_2O_4/UDMH) an initial weight of 150,000 pounds injected into a 60 hour transfer orbit is indicated. The use of hydrogen-oxygen propellants for return reduces the required injected weight to 100,000 pounds. In both cases it was assumed that the landing was accomplished with hydrogen-oxygen propellants.

Although the basic assumption was made that the Nova vehicle should be based on the use of storable propellants for the return because of advantages in reliability and better knowledge of propellant storage, a vigorous program should be pursued to develop the higher energy system.

While allowance has been made in both the velocity allowed and structure and propellant weights (such as a 2 minute hovering time) consistent with early accomplishment of the mission, there are many additional items that have not been accounted for.

At the present time it is difficult to assess all the unknown items that may contribute to increasing the requirement for payload capability. Past experience has generally indicated that the unknowns result in much greater requirements than are at first anticipated.

Following is a list of some factors not now accounted for that may tend to increase the spacecraft weight or reduce the Nova vehicle capability from the assumed values:

1. Quicker return in case of mission abort.
2. Attitude control of spacecraft.
3. Meteoroid protection of propellant tanks.
4. Variations in launch or flight trajectory.
5. Requirements for engine-out capability.
6. Higher gravity losses resulting from lower thrust levels.
7. Systems to prevent propellant freezing or boiling.
8. Heavier tank weights because of pressurized systems.
9. Launch problem from the moon.
10. Degree of hostility of lunar environment.

It was assumed that within the required time schedule, development of a Nova launch vehicle to a manned rating reliability is impossible. It is therefore necessary that the manned capsule be equipped with very reliable escape and abort propulsion systems which can in the event of a malfunction of any of the other stages safely return the spacecraft from any point in the launch trajectory. The propulsion aboard the spacecraft is therefore one of the most important systems.

There are three propulsion systems in the spacecraft:

1. Escape system.
2. Lunar landing system.
3. Lunar take-off system.

The highest reliability is required in the escape and lunar take-off systems.

Trajectories can be chosen which, without large payload penalties, allow safe return to earth with the lunar take-off system from any point in the trajectory beyond the earth orbit. By using a trajectory that includes a lunar orbit and a near horizontal landing, safe return can be accomplished with the lunar take-off system even in case of failure of the landing propulsion system.

The escape system is carried only during the initial launch through the atmosphere and then discarded. Its purpose is to carry the spacecraft clear of the launch vehicle in case of major malfunction or explosion. This system requires a high thrust and will probably use conventional solid rockets. Weight in this system is unimportant since these rockets are discarded in the early phase of the trajectory.

The lunar take-off propulsion has a thrust requirement (about 20,000 lbs) that makes it suitable for a number of missions which occur earlier. Some of these missions in addition to the lunar take-off are:

1. Landing system for Prospector.
2. Mission abort system (not escape) for the manned elliptical and circumlunar flights.
3. System for either mission abort or for orbiting and deorbiting the moon.
4. Third stage of Titan II.
5. Fifth stage of Saturn C-3 for deep space missions.

Reliability can be increased by repeated use of the system in these applications.

The general philosophy adopted is that all spacecraft propulsion systems be developed early and included on all vehicle or spacecraft development flights so that failure of any of the other systems will checkout the escape or abort propulsion. Low reliability of the launch vehicle, therefore, assures higher reliability in the safety systems.

LAUNCH VEHICLE CONFIGURATIONS AND PERFORMANCE

NOVA

Several configurations were considered for this study based on the use of F-1, J-2, a new 800 - 1000K pound thrust hydrogen-oxygen engine, and large solid motors of between 1.5 and 3.0M pound thrust in various combinations. Eight typical configurations, six Nova and two Saturn C-3 types, are outlined and their weight and performance characteristics shown in Figures B-2 to B-9. Payload performance calculations were based on the assumption that storable propellants would be used for the lunar take-off stage and included a 3% velocity margin. Five of the configurations are based on the use of three stages to escape velocity. The sixth configuration employs two solid stages and two liquid stages to escape.

Nova I

This vehicle is based on developing a module consisting of 2 F-1 engines and associated tankage and propellants. This three million pound thrust module can be used as the first stage of a C-3 vehicle, the second stage of Nova I and, in a cluster of four modules as the first stage of Nova I, II, or III. This configuration consists of four 2 F-1 modules clustered for the first stage, one 2 F-1 module for the second stage and a four J-2 hydrogen-oxygen third stage. The escape payload capability is about 115,000 pounds. The stage diameters and lengths, weights and mass fractions and significant values of dynamic pressure are shown in figure B-2.

For comparison purposes a single tank for the first stage of Nova I was also considered and comparable sizes, weights, etc. are shown in figure B-3. Because of the better structural efficiency of the single tank the escape payload for this configuration is increased to about 125,000 pounds. Both these vehicles have a capability less than the 150,000 pounds desired and are sensitive to third stage structural weights. The best payload capability would be obtained with exceptionally large propellant loadings in the third stage (approximately 1.5M pounds).

Nova II

This vehicle is similar to the Nova I with the single tank first stage except the second stage uses high energy propellants and a cluster of eight J-2 engines. A new 800 to 1000K thrust engine in a cluster of two could be used and give essentially the same performance. The second stage is underpowered from an optimization standpoint but still provides a significant increase in payload capability over Nova I to about 160,000 pounds to escape.

The third stage is the same diameter as the third stage for Nova I but is only half as long. Significant weights, dimensions, etc. are shown in figure B-4. If engine-out capability is shown to be feasible for the second stage of this configuration with the J-2 engines the overall reliability could be increased with only a relatively small decrease in payload capability (about 10,000 pounds). It is also possible to stage this vehicle in orbit, if desired, with only a slight decrease in payload.

Nova III

The second stage of Nova III uses a cluster of four new H/O engines of 800 - 1000K pound thrust each. This would overcome the thrust deficiency in the second stage of Nova II and should result in higher overall reliability since the total number of engines is reduced. The escape payload capability is increased to about 190,000 pounds and the overall vehicle length is essentially the same as the Nova II. This configuration provides assurance of meeting larger payload requirements if they are found necessary and could be developed in essentially the same time scale as the Nova II but with less assurance, if initiation of the development of the large H/O engine was immediate. Significant weights, dimensions, etc. are shown in figure B-5.

Nova IV

This configuration is shown in two versions. The first is a four stage vehicle to escape and employs clusters of solid motors in the first and second stages. Separation of the third and fourth stage occurs in the parking orbit. The payload capability of this system is comparable to that for Nova II but requires a much higher lift-off thrust. In addition, the dynamic pressure at separation of first and second stages is high (400 psf) which may impose problems in dynamics and the spacecraft abort sensing system. This high Q is associated with short burning time as compared to liquid stages although the burning time assumed of 85 seconds is higher than any solid motor today. Nozzles and vector controls will have to be designed to withstand the high temperatures associated with the longer burning time. This configuration is shown in figure B-6.

The second configuration is a three stage vehicle to escape and uses one solid stage to replace the 8 F-1 liquid stage used in Novas I, II, and III. This stage must have more thrust and a longer burning time and problems associated with nozzles and controls are therefore compounded. The dimensions, weights, etc. for this configuration are shown in figure B-7.

SATURN C-3

The two C-3 configurations considered for this study were based on using two F-1 engines in the first stage or a cluster of solid motors. In the case of Nova I the second stage would be the same size, weight and thrust as the first stage of C-3. In the case of C-3 solid first stage it would be the same size, weight and thrust as the second stage of the four stage solid Nova.

These two vehicles have an escape capability of 30 to 35,000 pounds and would be used to perform the manned elliptical, circumlunar, and lunar orbiting missions. A vehicle between the C-1 and Nova class was determined as essential to the manned lunar landing program. The pertinent dimensions, weights, etc. for the liquid C-3 and solid C-3 are shown in figures B-8 and B-9, respectively.

VEHICLE SUMMARY

Table B-IV summarizes the six Nova and the two C-3 vehicles considered with respect to size and payload capability. If it is assumed that the three-man capsule (at earth re-entry) weighs 12,500 pounds as a requirement for Nova, then the escape capability must be approximately 150,000 pounds if storable propellants (305 sec. specific impulse) are used. The development efforts associated with the use of high energy propellants for the return stage should be pursued vigorously in the event the capsule weight grows because of unforeseen penalties imposed by having to provide artificial gravity or more shielding than is presently contemplated.

As indicated by the summary chart, Nova II and Nova IV are capable of providing the required escape capability while Nova III provides a generous margin. Nova I does not provide sufficient capability and although the escape payload can be increased to about 140,000 pounds using optimistic assumptions regarding propellant loading and structural weights, the attainment of this value is extremely doubtful. Nova I is the only vehicle that requires altitude start of the F-1 engine, so that this requirement of the F-1 does not appear necessary.

Some general comments on the configurations considered and their performance are:

a. The mass fractions used are considered to be realistic for the time period assumed and are substantiated by many studies performed by outside contractors.

b. Tankage compatibility has been an important consideration in stage sizing and as an example the upper stages for Nova II are identical to the upper stages of the four stage solid Nova IV. When a final configuration is selected, stage diameters may be changed for ease of fabrication.

c. In all liquid Nova configurations the first stage tank construction could be either a single tank or a cluster of tanks. The decision on the Nova design does not have to be made now, but a contract for design and hardware procurement should be let as early as possible so that decisions affecting facilities can be made as early as possible. Figure B-10 lists some of the advantages of each type of construction. The capabilities of the stage contractor must also be considered and the final structural arrangement must be the result of evaluating trade-offs of manufacturing, transportation and handing, technical state-of-the-art, and cost.

d. Slight variations in trajectory shape can give large variations in dynamic pressure without significantly affecting payload capability.

e. With proper thrust variation during solid stage burning, a considerable reduction in the problems associated with the solid Nova vehicles can be achieved. These could include reduced take-off thrust and therefore noise level in the launch area and the maximum and separation values of q.

f. The solid propellant motors should be developed so that they provide a complete backup to the F-1 engine program until its feasibility can be demonstrated with several full duration firings. None of the solid vehicles proposed, therefore, use the F-1 engine. Once feasibility is demonstrated, however, combinations could be considered.

DEVELOPMENT SCHEDULES

VEHICLES CONSIDERED

As stated in the previous section, several Nova and C-2 configurations were considered in this study. Preliminary analyses of development schedules indicated that the type of configuration did not have a significant effect on either time or cost. Further consideration was therefore limited to one Nova and one C-3 each of both all-liquid and solid-liquid types. These four vehicles are:

Nova II - all-liquid propellant
C-3 - all-liquid propellant
Nova IV - solid-liquid propellant, four stage
C-3 - solid-liquid propellant

SCHEDULE DERIVATION

The development and funding schedules, critical action dates and launch dates for these vehicles were established with the aid of the NASA Sequenced Milestone System (SMS). Figures B-11, B-12, B-13, and B-14 are the SMS sequence networks and show the final results of several successive computer analyses of the network data.

Establishment of realistic time intervals for each milestone is an iterative process. Initially, each task was viewed as a pacing item, and an estimate of minimum feasible time for accomplishment was made. Computer analysis then showed which milestone chains (paths) were pacing and required further consideration. Time estimates were then revised and schedule dates were adjusted on the basis of best currently available information and judgement and the whole process of computer analysis and network revision repeated until a feasible schedule resulted. Finally, those paths which were non-pacing were stretched out, partly by increasing time allowances for individual tasks and partly by delaying initiation of tasks. The purpose of this step was to provide a more reasonably paced program. This action reduces costs in the early phases of the program and avoids doing all tasks on a crash basis.

It will be noted that facilities required for development, manufacture, and launch of the vehicles are included. This is essential to the development of realistic schedules.

The final computer analysis for each network chart is included as Table B-V, B-VI, B-VII, and B-VIII. These particular tabulations are arranged to show the slack time (excess time allowed) in the various paths. For example, Table B-V for Nova II shows a path of 16 milestones with a slack of 1.4 weeks; slippage could occur in this sequence up to a total of 1.4 weeks without causing over-all program slippage.

Negative numbers in the slack time column indicate that the sequence cannot be completed in the time allowed. Also shown in these tables is the "Expected Date" for each milestone (computed on the basis of time estimates for each milestone), the "Latest Allowable Date" (the latest completion date which would not cause program slippage) and a "Schedule Date" which falls between the other two dates. In general, the Schedule Date is the Latest Allowable Date set forward to provide insurance against excessive slippage of individual milestones.

SCHEDULES

Figures B-15 and B-16 summarize the development schedules for the all-liquid and solid-liquid vehicles, respectively. Only the most critical of the major tasks are shown; details may be obtained by reference to the appropriate charts. Dates indicated are Schedule Dates or Expected Dates, as appropriate. It is noted that the pacing items in development of these vehicles are facilities and engines. The SMS analyses of the four vehicles programs shows that launch dates for the liquid and solid C-3's are identical, and that the date for the solid-liquid Nova for the first manned lunar landing flight lags the all-liquid Nova by about three months (fourth and third quarters of calendar year 1967, respectively). It will be noted that one more flight is scheduled for the solid-liquid than the all-liquid Nova before the scheduled manned flight. This difference is attributable to the difference in number of stages assumed.

In arriving at these schedules, it was assumed that critical events would be accomplished on a high priority basis, e.g. contracts for critical stages and test stands would be awarded in not more than 12 weeks, and A&E contracts for required launch complexes would be awarded almost immediately. It is believed that the over-all program schedule is technically feasible but requires timely and adequate funding and strong effective management.

For the Nova vehicles, fourteen weeks were allowed between launches from a single stand, yielding an average of seven weeks between vehicles. This is considered the minimum feasible allowance for incorporation of changes between flights. Decreasing this interval therefore would not accelerate the program but would simply require more vehicles. The number of flights selected is the minimum considered necessary to provide reasonable confidence for mission success. As indicated previously "man-rating" is not directly a criterion since reliance for safety is placed on the escape and abort systems.

ENGINE DEVELOPMENT SCHEDULE

Figure B-17 presented the development schedule for the F-1, J-2, and new large H_2-O_2 (800-1000K) engines, and two lunar take-off propulsion systems.

F-1 and J-2

Both the F-1 and J-2 development schedules and first engine delivery dates are consistent with the liquid Nova and C-3 development schedules presented earlier.

Large Solid Motor

The large solid motor development will have its first firing of a pre-prototype engine in September of 1962 and some 5 full duration firings by July 1963. By this time the flight configuration and the flight thrust vector system will have been ground tested. The large solid motor development is an extension of the state-of-the-art and as such the engine schedule presented cannot be assured. Since first flight occurs early in 1965 for the C-3 and late in 1965 for Nova there is additional time available for the motor development. The development times are consistent with the Nova and C-3 development schedule presented earlier.

800 - 1000 K Engine

The large H_2-O_2 engine development should be initiated at once as indicated on figure B-17. The west coast supply of hydrogen can be supplemented by hydrogen from Florida while a new plant is erected. It is believed that flight engines can be made available about 30 months after contract award. This is some 12 months later than some industry sources indicate a safe ground test engine can be delivered to the stage contractor for systems firings. It appears that such an engine can meet the Nova flight schedule.

Again like the solid engine this is an extension of the current state-of-the-art of H_2-O_2 rockets and as such the schedule cannot be assured. The fact that the engine would not fly until early 1966 in Nova and early 1965 in C-3 gives reasonable additional time for engine development.

Lunar Return Propulsion System

As indicated earlier both high energy and low energy propellant storable propulsion systems are proposed for development. Both are started early because of the high reliability requirement associated with their use as the abort propulsion system during most of the flight. Since this abort system must always operate and may have to be relit if it does any of the final lunar landing maneuver, consideration should be given to using hypergolic propellants. Furthermore, to simplify the system, pressure fed engines rather than turbopump engines should be considered.

One of these propulsion systems will be selected for the manned lunar mission and will be very extensively flight tested. The period shown as flight testing starts with flights on Saturn C-1 when the spacecraft is undergoing suborbital re-entry and orbital qualification testing, and lunar landing and take-off manned training missions. It continues through the re-entry qualification on C-3 and the manned elliptical, circumlunar, and lunar orbiting flights.

DECISION POINTS

NOVA II OR NOVA III SELECTION

Figure B-18 shows that a selection of the second stage propulsion system is required by September 1962 in order to meet the vehicle development schedule. It may be reasonably expected that a higher reliability can be eventually achieved in that stage by using a fewer number of the larger H_2-O_2 engines than 8 J-2 engines. Whether the larger engine can be developed with sufficiently high reliability to achieve the manned lunar landing in the desired time is, of course, open to question. The relative reliability of the two systems also depends on whether engine-out capability can be achieved in the 8 engine cluster.

If development of the new engine is initiated immediately, however, sufficient experience should be available in both systems on which to make a rational decision by the time a decision is required.

SELECTION OF SOLID OR LIQUID NOVA AND C-3

Figure B-18 indicates that the earliest date on which a decision can be made between the use of F-1's or solid rockets in Nova is July 1962. At this time some 40 full duration runs on the F-1 are scheduled for completion and the feasibility of the F-1 will have been demonstrated. However, the first prototype large solid motor will not yet have been fired. By deferring a decision until July 1963 (1 year later) the F-1 will have had over 100 full duration runs and the solid motor some 5 runs. By this time the flight thrust vector system for the solid motor will also have been tested.

Table B-IX presents the effect on vehicle development cost of when the decision to develop a single Nova and C-3 is made. If the decision were made in July 1962 the vehicle development cost is reduced about 2.5 billion dollars. Deferring a decision until July 1963 adds approximately 500 million dollars to the program cost and a July 1964 decision adds another 900 million. Development of 2 Nova and 2 C-3 vehicles all the way would increase the total program cost about 2.5 billion dollars.

ACTION ITEMS

One of the ground rules of this study was that both a solid-liquid and an all-liquid Nova and C-3 vehicle development must be initiated until assurance that one or the other will be successful is established. To accomplish the manned lunar landing in 1967, the R&D contract award dates for all four vehicles are outlined in Table B-X for FY 1962 and 63.

To permit all 4 vehicles to meet the spacecraft and vehicle flight development plan presented in the spacecraft section, all four first stage contracts must be awarded in the first quarter of FY 1962. The initial efforts on these contracts will include vehicle design, organization buildup, procurement of long lead hardware, and test and manufacturing facilities design and construction.

Early initiation of both the low-energy and the high-energy lunar-return propulsion systems development is essential. These are also the abort propulsion system and as such must be man-rated and highly reliable.

In addition to the vehicle R&D contract actions listed there will be an extensive listing of test facilities contract awards presented in the facilities section.

TABLE B-I: Basic Assumptions

1. Nova vehicles to have direct flight manned lunar payload capability.
2. Storable propellant lunar return propulsion system.
3. Vehicle configurations capable of mission accomplishment by 1967 considered.
4. Performance quotations must be consistent with tight development schedule.
5. Solid and liquid Nova development assumed at outset.
6. Vehicle required for payloads between Saturn C-1 and Nova.
7. Nuclear upper stages not considered in this period.

TABLE B-II: Mission Requirements

C-1 Missions

Spacecraft sub-orbital re-entry and orbital qualification.

C-3 Missions

Spacecraft re-entry qualification.
Elliptical, circumlunar, and lunar orbiting flights (with spacecraft.
Prospector.

Nova Missions

Manned lunar landing and return.

CONFIDENTIAL

TABLE B-III : Spacecraft Propulsion Weights

Maneuver	Weight, lb	
	Storable return (I_{sp} = 305 sec)	H_2/O_2 return (I_{sp} = 420 sec)
Injected to 60 hr. transfer orbit	150,000	100,000
Propellants for midcourse correction (150 ft/sec)*	1,800	1,000
Propellants for braking to lunar orbit (3400)	33,000	22,000
Propellants for descent (6680)	45,000	30,000
Propellants for hovering 2 minutes (650)	3,200	2,000
Landed on lunar surface	67,000	45,000
Landing gear (6% of landed weight)	4,000	2,700
Propulsion structure	10,500	7,000
Return take-off weight	52,500	35,300
Propellants for ascent to lunar orbit (7600)	28,000	15,000
Propellants for 60 hr. return injection (3400)	7,200	4,400
Propellants for midcourse correction (150)	300	200
Total return weight	17,000	15,700
Propulsion structure	4,500	3,200
Capsule re-entry weight	12,500	12,500

*Velocity requirement of maneuver

CONFIDENTIAL

TABLE B-IV : Summary Performance Capabilities

Vehicle	Escape Payload, lb.	Overall Length, ft.	Maximum Diameter, ft.
NOVA I (Cluster tank) 8 F-1, 2 F-1, 4 J-2	115,000	330	65
NOVA I (Single tank) 8 F-1, 2 F-1, 4 J-2	125,000	345	44
NOVA II (Single tank) 8 F-1, 8 J-2, 2 J-2	160,000	335	44
NOVA III (Single tank) 8 F-1, 4 Y-1, 4 J-2	190,000	330	50
NOVA IV (Clustered solid) 7 solids (17M), 4 solids (7M), 8 J-2, 2 J-2	160,000	380	42
NOVA IV (Clustered solid) 8 solids (21M), 8 J-2, 2 J-2	160,000	320	45
C-3 (Liquid) 2 F-1, 4 J-2, 6 LR-115	30,000	230	27
C-3 (Solid) 4 solids (7M) 4 J-2, 6 LR-155	35,000	215	33

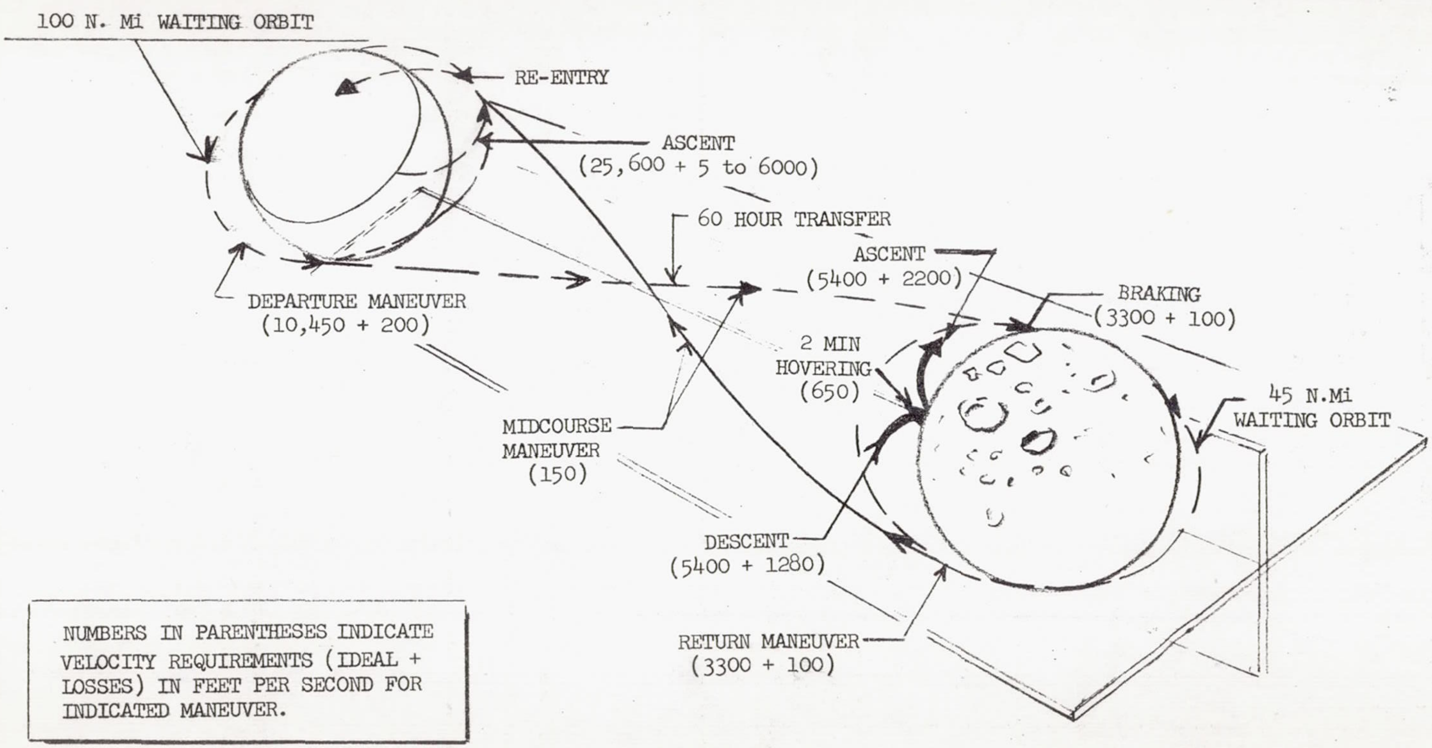
TABLE B-IX: VEHICLE DEVELOPMENT COST AS AFFECTED BY THE DECISION DATE FOR SELECTION OF SINGLE NOVA & C-3 VEHICLE

Date of Selection of Single Nova & C-3 Vehicle	Estimated Total Nova & C-3 Development Cost, Millions of Dollars	Reduction in Cost Associated with Single Vehicle Selection
July 62	5,500	2,500
July 63	5,900	2,100
July 64	6,800	1,200
Development of both Liquid & Solid Nova & C-3	8,000	Not applicable

TABLE B-X: Contract Action Required for R&D
(For Nova II & Liquid C-3 & Nova IV & Solid C-3)

FY 62	FY 63
1st QUARTER 1. Nova liquid first stage 2. Nova solid first stage 3. C-3 liquid first stage 4. C-3 solid first stage 5. Large H_2-O_2 engine (800-1000 K) 6. Large solid motor	1st QUARTER 1. None
2nd QUARTER 1. Lunar return propulsion - (storable propellants) 2. Lunar return propulsion - (high-energy propellants)	2nd QUARTER 1. Nova solid second stage 2. C-3 third stage
3rd QUARTER 1. C-3 second stage (S-II) 2. Nova liquid second stage	3rd QUARTER 1. Nova liquid third stage
4th QUARTER 1. None	4th QUARTER 1. None

CONFIDENTIAL

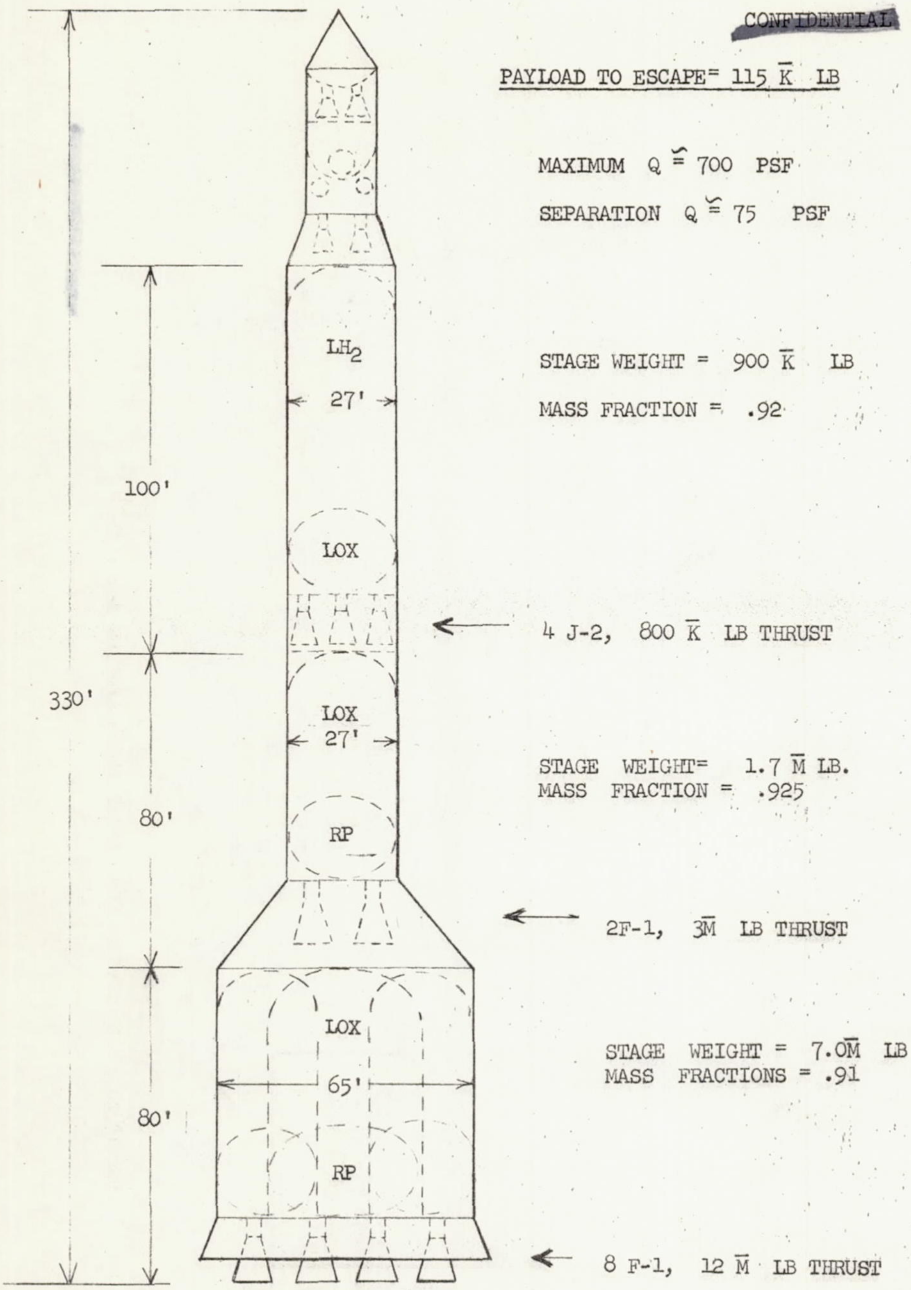


PROPULSION REQUIREMENT FOR MANNED LUNAR LANDING AND RETURN

FIGURE B-1

CONFIDENTIAL

~~CONFIDENTIAL~~

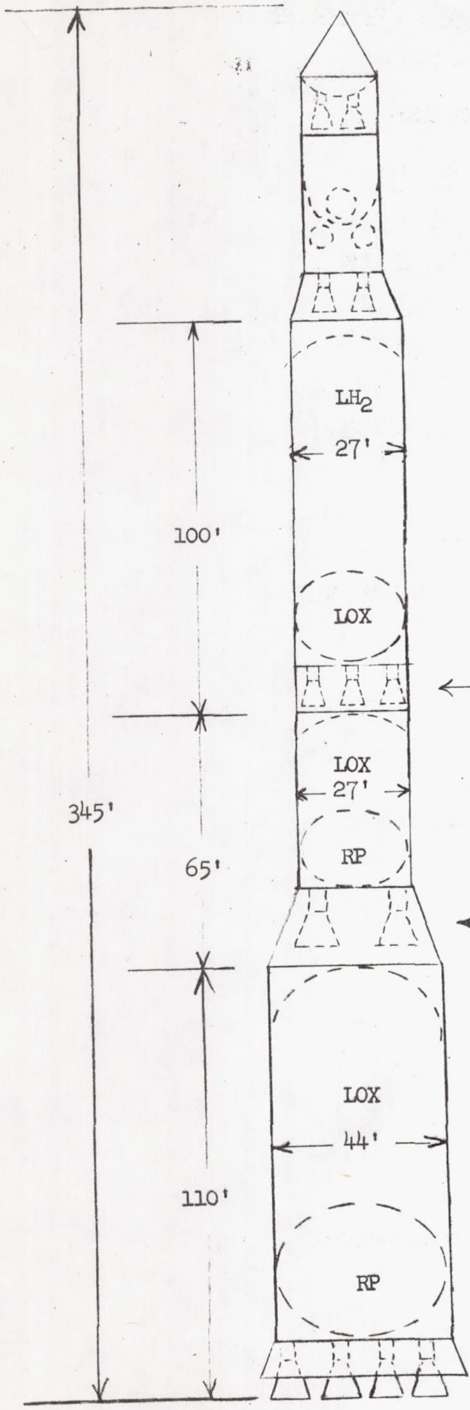


NOVA I - CLUSTERED TANK

~~CONFIDENTIAL~~

FIGURE B- 2

CONFIDENTIAL



PAYLOAD TO ESCAPE = 125 $\bar{K}$ LB

MAXIMUM Q $\cong$ 700 PSF

SEPARATION Q $\cong$ 25 PSF

STAGE WEIGHT = 900 $\bar{K}$ LB

MASS FRACTION = .92

4 J-2, 800 $\bar{K}$ LB THRUST

STAGE WEIGHT = 1.2$\bar{M}$ LB
MASS FRACTION = .91

2 F-1, 3 $\bar{M}$ LB THRUST

STAGE WEIGHT = 7.5$\bar{M}$ LB
MASS FRACTION = .93

8 F-1, 12 $\bar{M}$ LB THRUST

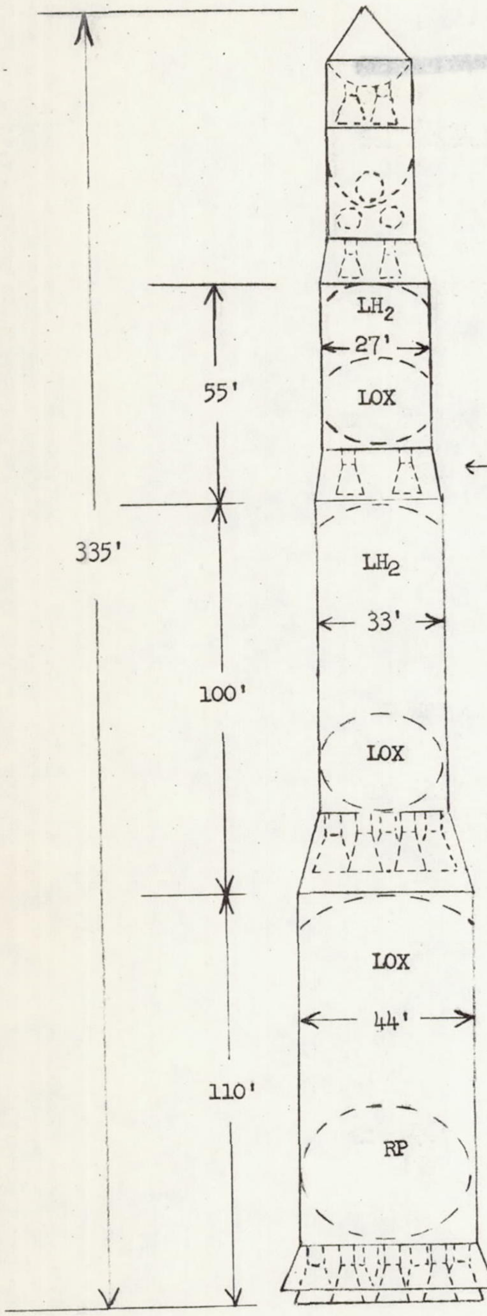
NOVA I - SINGLE TANK

FIGURE B- 3

CONFIDENTIAL

CONFIDENTIAL

PAYLOAD TO ESCAPE 160 $\bar{K}$ LB



MAXIMUM Q $\cong$ 650 PSF

SEPARATION Q $\cong$ 15 PSF

STAGE WEIGHT = 500 $\bar{K}$ LB

MASS FRACTION = .91

2 J-2, 400 $\bar{K}$ LB THRUST

STAGE WEIGHT = 1.4 $\bar{M}$ LB

MASS FRACTIONS = .92

8 J-2, 1.6 $\bar{M}$ LB THRUST

STAGE WEIGHT = 7.5$\bar{M}$ LB

MASS FRACTION = .93

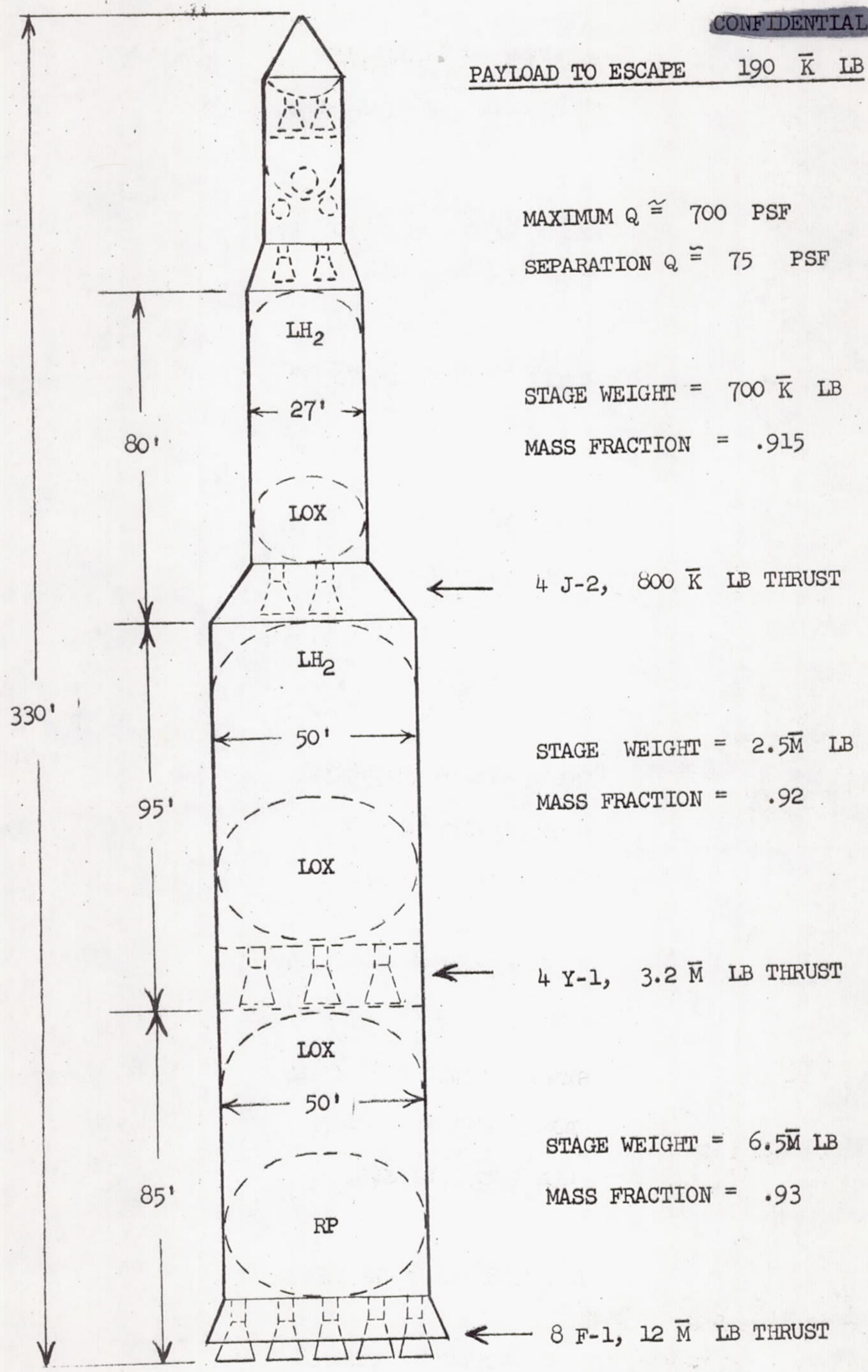
8 F-1, 12 $\bar{M}$ LB THRUST

NOVA II - SINGLE TANK

CONFIDENTIAL

FIGURE B- 4

CONFIDENTIAL



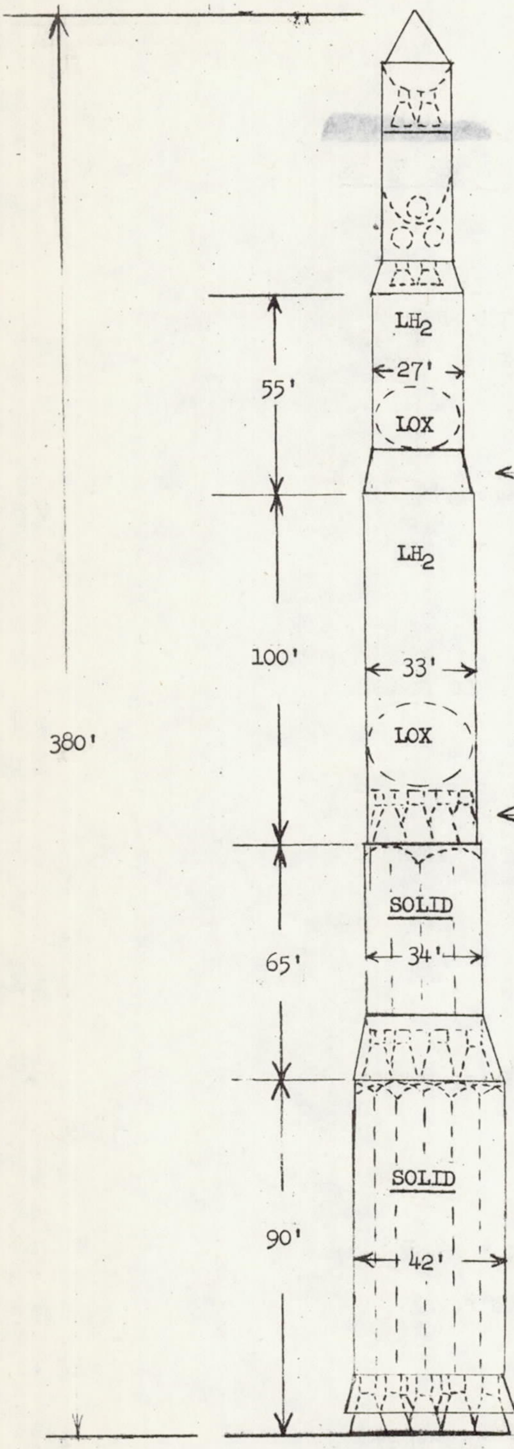
NOVA III - SINGLE TANK

CONFIDENTIAL

FIGURE B-5

CONFIDENTIAL

PAYLOAD TO ESCAPE = 160 $\overline{K}$ LB



MAXIMUM Q ≅ 800 PSF

SEPARATION Q ≅ 400 PSF

STAGE WEIGHT = 500 $\overline{K}$ LB

MASS FRACTION = .91

2 J-2, 400 $\overline{K}$ LB THRUST

STAGE WEIGHT = 1.4 $\overline{M}$ LB

MASS FRACTION = .92

8 J-2, 1.6 $\overline{M}$ LB THRUST

STAGE WEIGHT= 2.94 $\overline{M}$ LB

MASS FRACTION = .86

BURN TIME = 85 SEC.

4 MOTORS, 7- $\overline{M}$ LB THRUST

STAGE WEIGHT= 6.86 $\overline{M}$ LB

MASS FRACTION= .86

BURN TIME = 85 SEC.

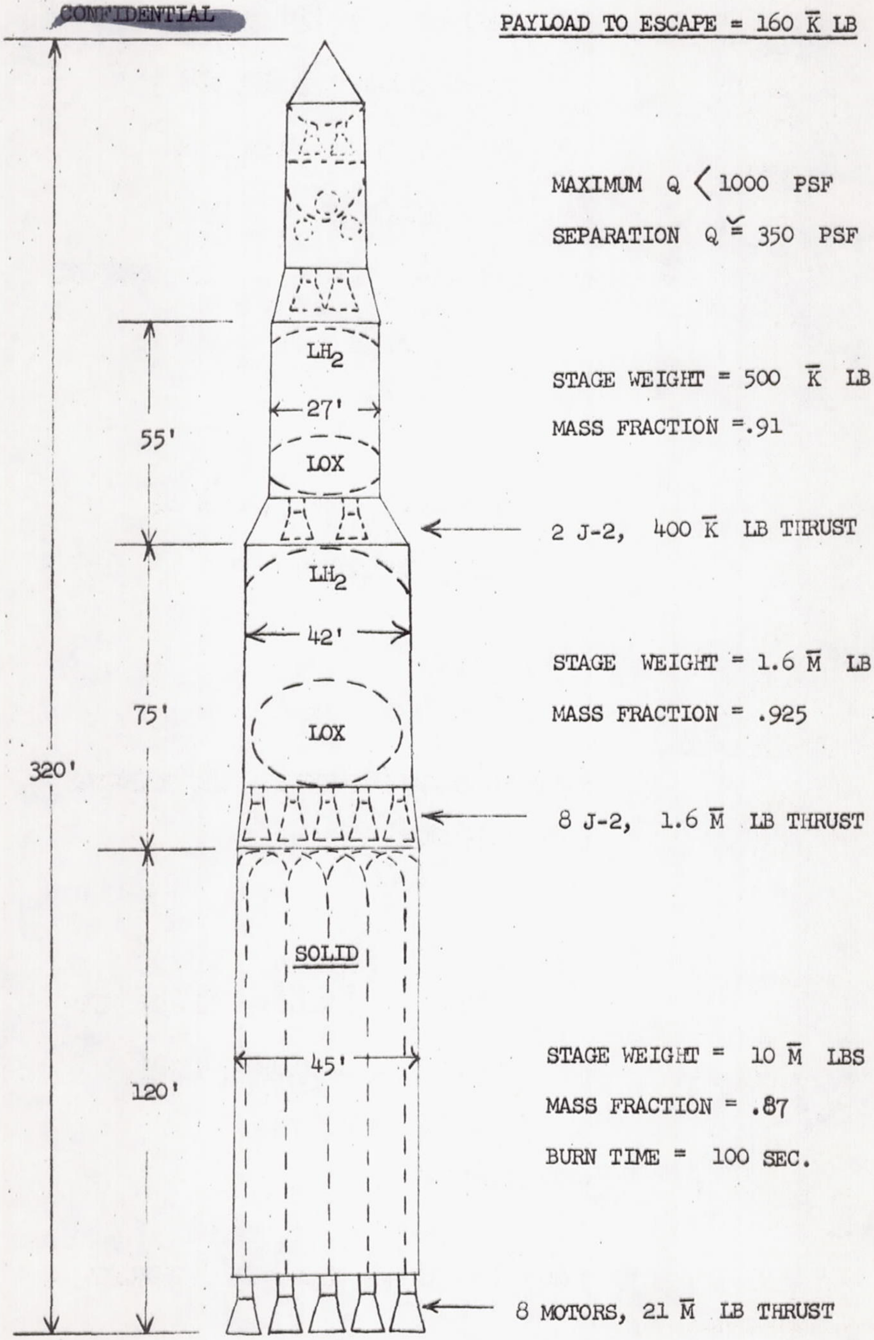
7 MOTORS, 17 $\overline{M}$ LB THRUST

NOVA IV - CLUSTERED SOLID (4 STAGES TO ESCAPE)

CONFIDENTIAL

FIGURE B- 6

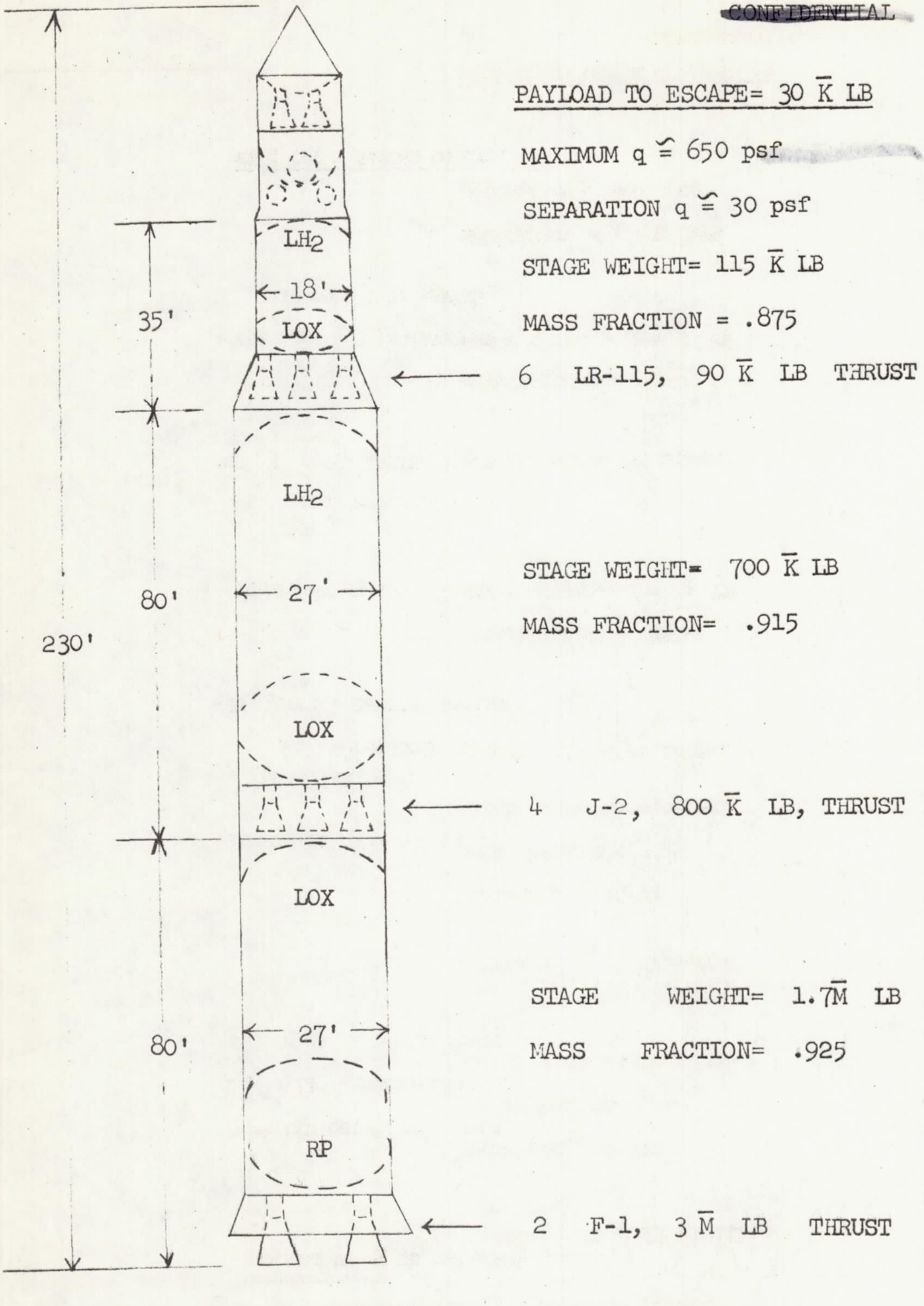
CONFIDENTIAL



NOVA IV - CLUSTERED SOLID
(3 STAGES TO ESCAPE)

FIGURE B- 7 CONFIDENTIAL

~~CONFIDENTIAL~~



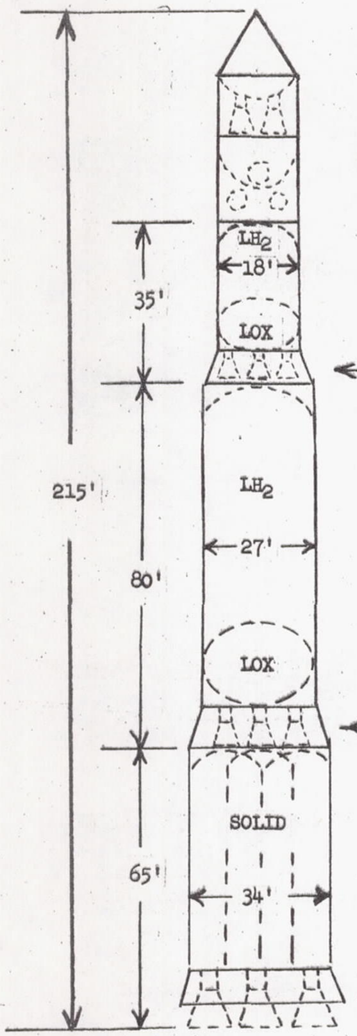
C-3 LIQUID

FIGURE B- 8

~~CONFIDENTIAL~~

CONFIDENTIAL

PAYLOAD TO ESCAPE= 35 $\bar{K}$ LB



MAXIMUM $q \cong$ 1000

SEPARATION $q \cong$ 700

STAGE WEIGHT = 115 $\bar{K}$ LB

MASS FRACTION= .875

6 LR-115, 90 $\bar{K}$ LB. THRUST

STAGE WEIGHT= 700 $\bar{K}$ LB

MASS FRACTION= .91

4 J-2, 800 $\bar{K}$ LB THRUST

STAGE WEIGHT= 2.94 $\bar{M}$ LBS

MASS FRACTION= .86

BURN TIME = 85 SEC

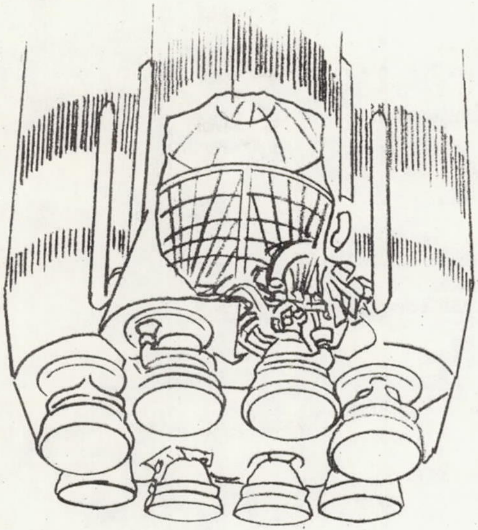
4 MOTORS, 7 $\bar{M}$ LB THRUST

C-3 - SOLID

FIGURE B- 9 CONFIDENTIAL

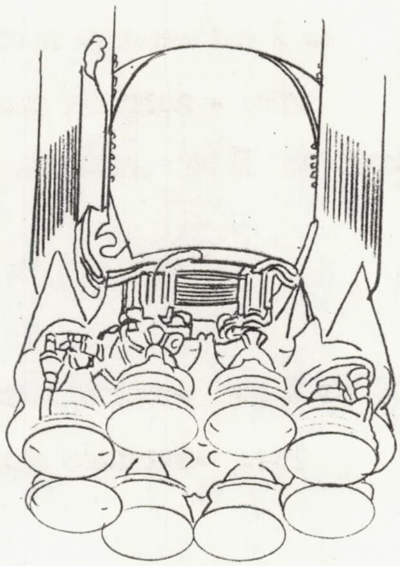
~~CONFIDENTIAL~~

CLUSTERED TANK



1. HEAT TREATING FACILITIES AVAILABLE
2. FABRICATION TECHNIQUES BETTER KNOWN
3. APPLICABLE TO C-3
4. EASIER TO TRANSPORT AND HANDLE
5. PROVIDES FOR MAXIMUM NO. OF STATIC TESTS
6. BETTER KNOWN SLOSHING CHARACTERISTICS

SINGLE TANK



1. EASIER TO PROVIDE ENGINE OUT CAPABILITY
2. BETTER STRUCTUAL EFFICIENCY
3. HIGHER PAYLOAD CAPABILITY
4. BETTER 1st STAGE BENDING CHARACTERISTICS
5. SIMPLER VEHICLE DESIGN

COMPARISON OF FIRST STAGE TANK CONFIGURATIONS FOR LIQUID NOVA (PROPELLANT LOX/RP)

FIGURE B-10

~~CONFIDENTIAL~~

FIGURE B-11

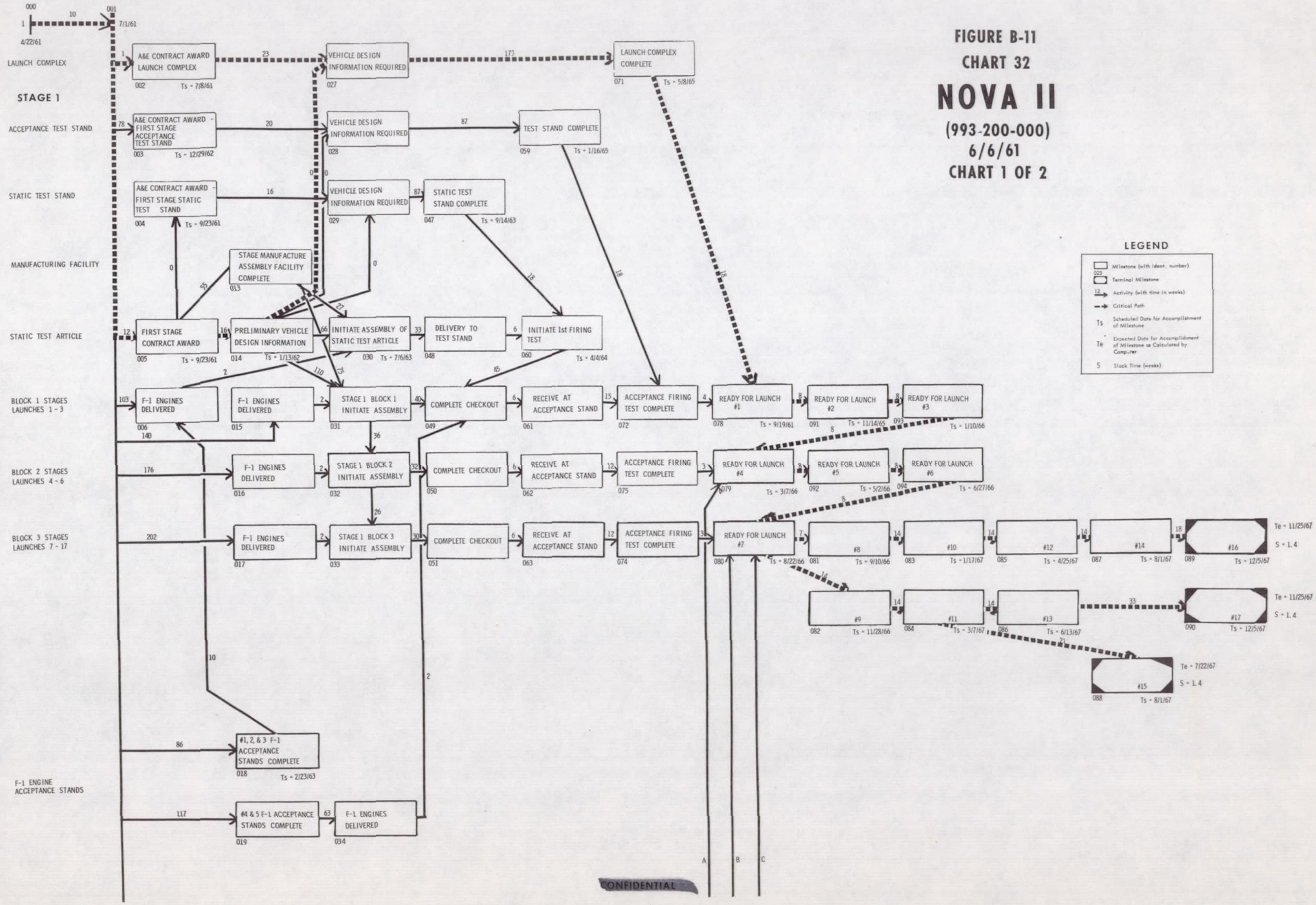
CHART 32

NOVA II

(993-200-000)

6/6/61

CHART 1 OF 2



~~CONFIDENTIAL~~

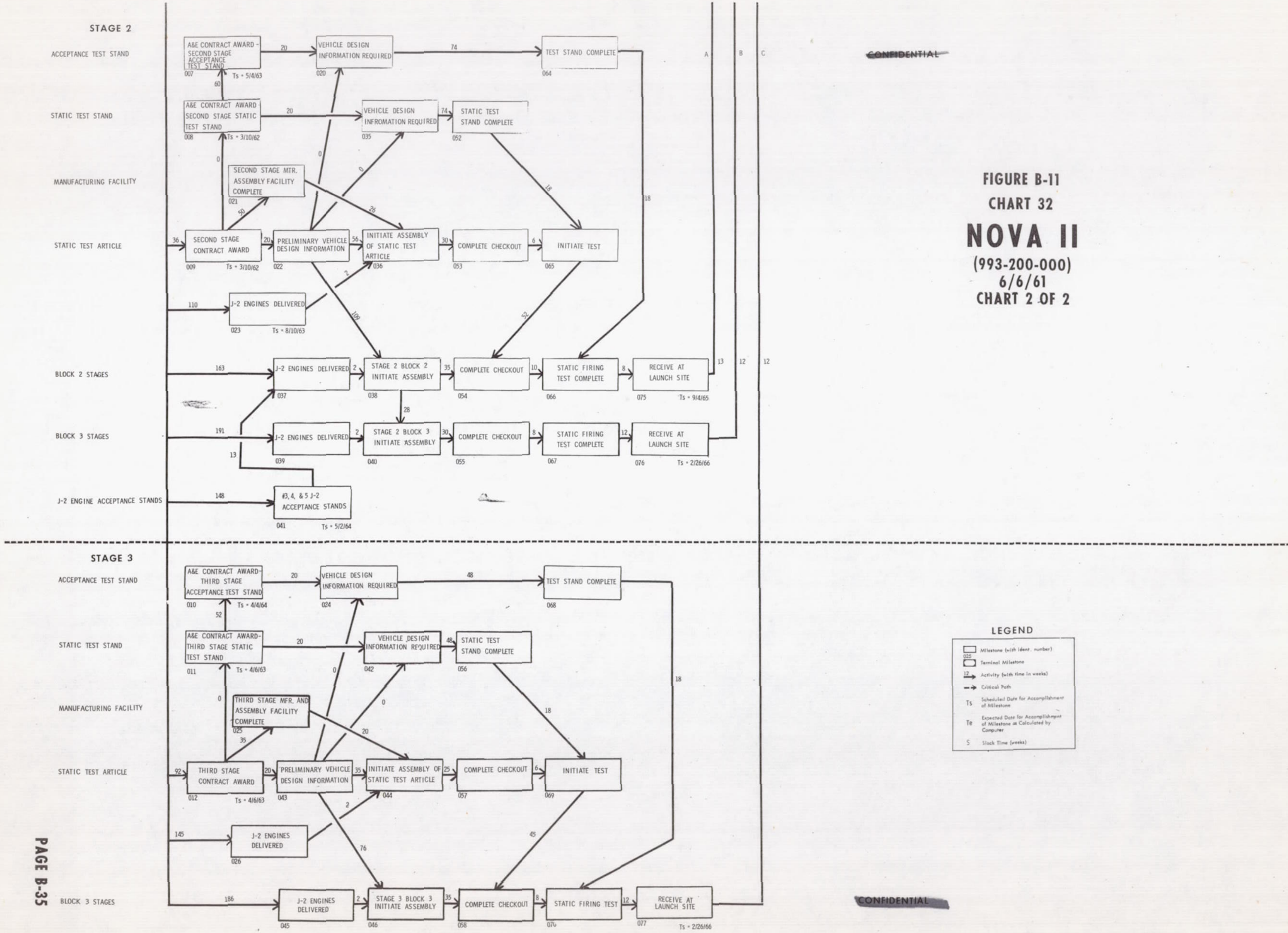


FIGURE B-11
CHART 32
NOVA II
(993-200-000)
6/6/61
CHART 2 OF 2

LEGEND

Milestone (with ident. number)
Terminal Milestone
Activity (with time in weeks)
Critical Path
Ts Scheduled Date for Accomplishment of Milestone
Te Expected Date for Accomplishment of Milestone as Calculated by Computer
S Slack Time (weeks)

CONFIDENTIAL

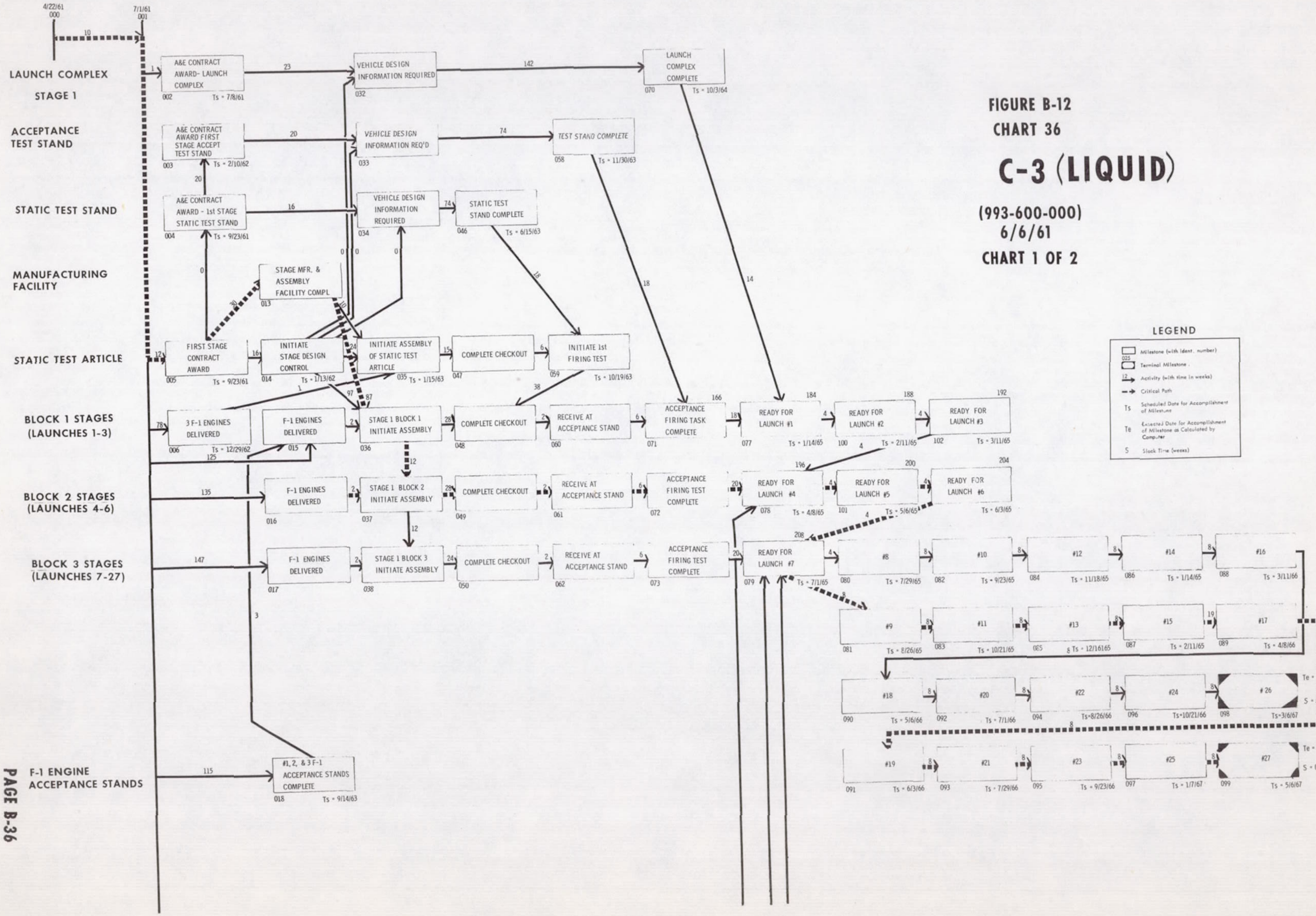


FIGURE B-12
CHART 36

C-3 (LIQUID)

(993-600-000)
6/6/61
CHART 1 OF 2

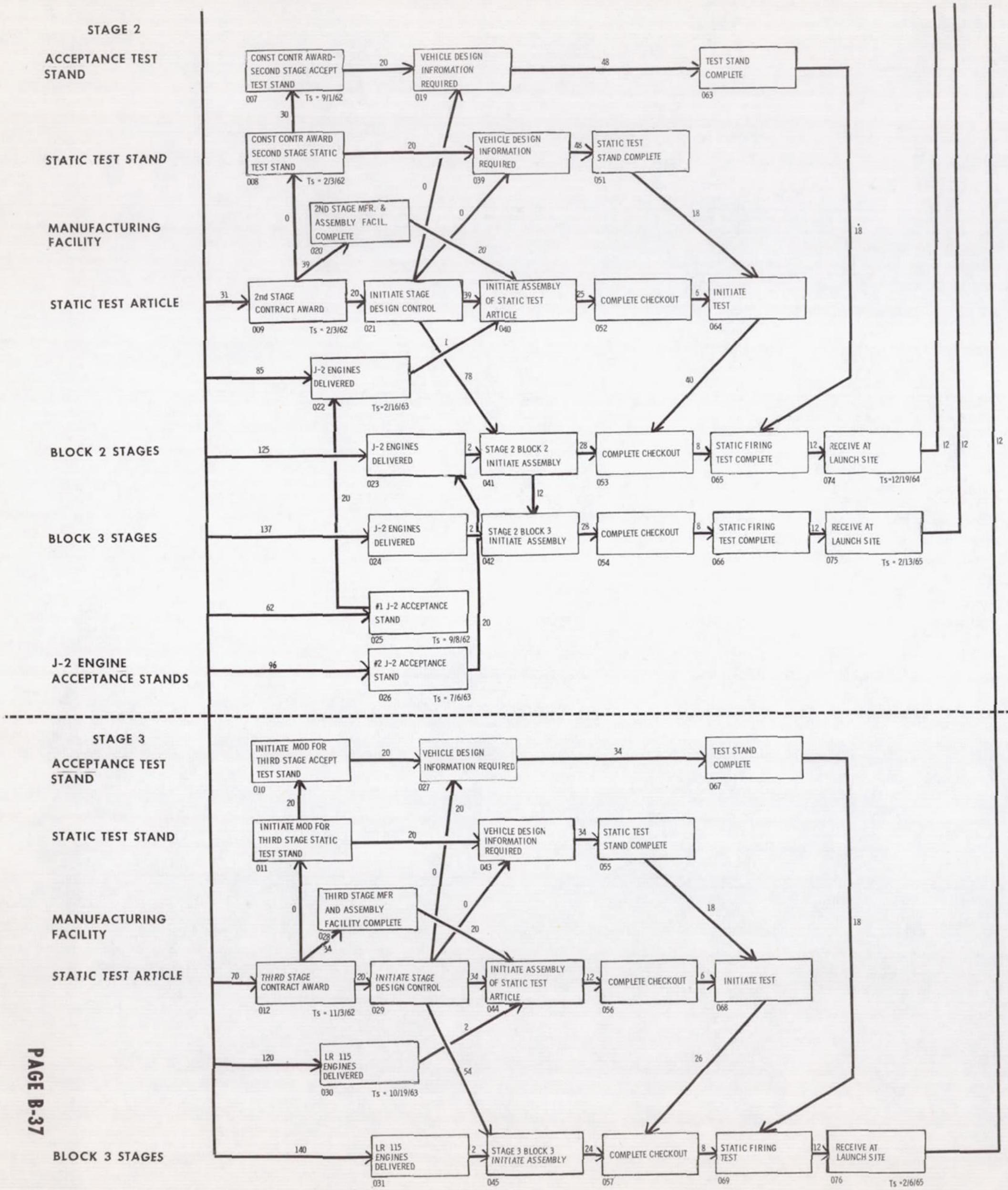
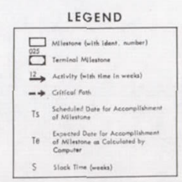


FIGURE B-12
CHART 36

C-3 (LIQUID)

(993-600-000)
6/6/61

CHART 2 OF 2



~~CONFIDENTIAL~~

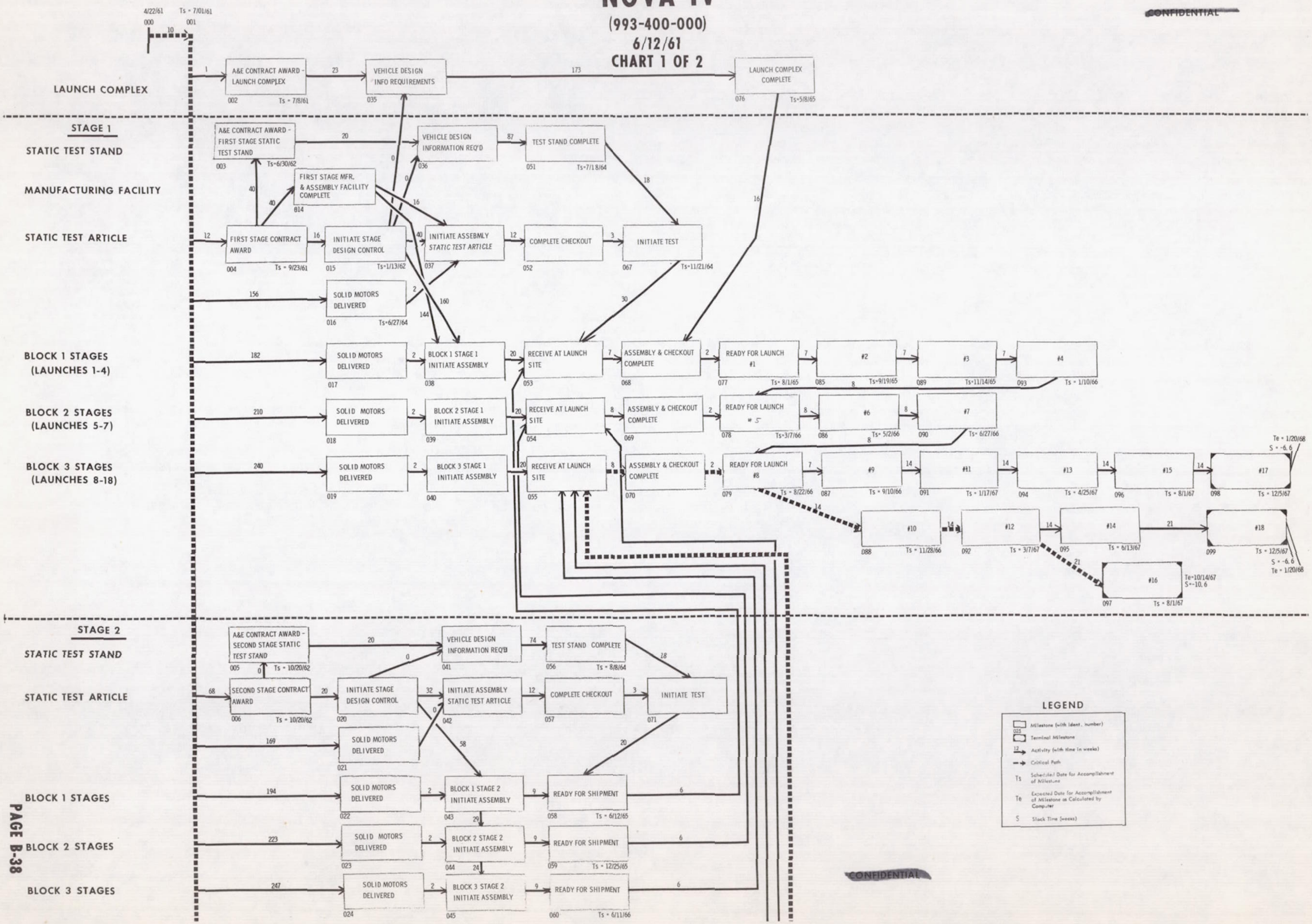
CHART 34 FIGURE B-13

NOVA IV

(993-400-000)

6/12/61

CHART 1 OF 2



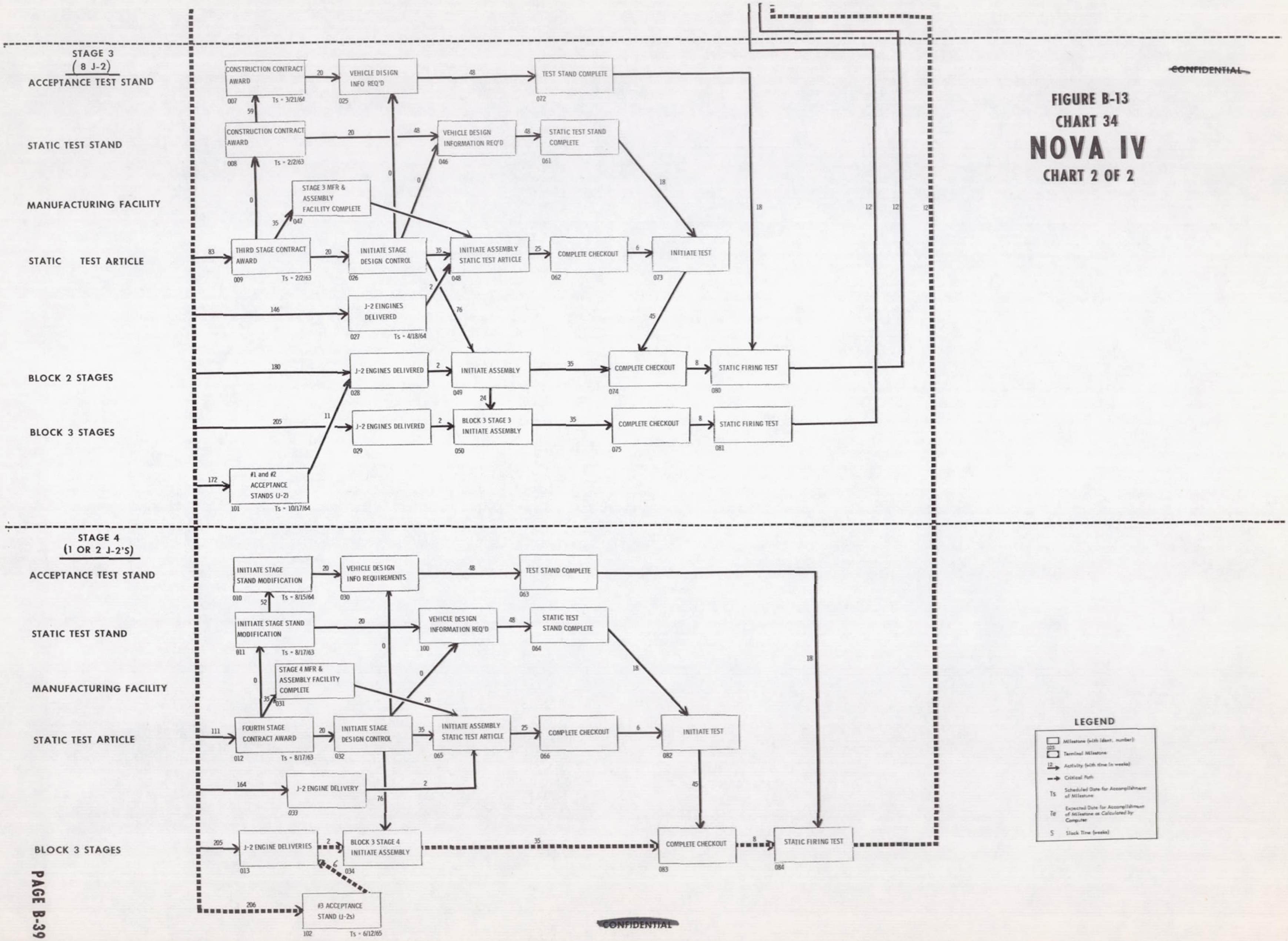
~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

FIGURE B-13
CHART 34

NOVA IV

CHART 2 OF 2



~~CONFIDENTIAL~~

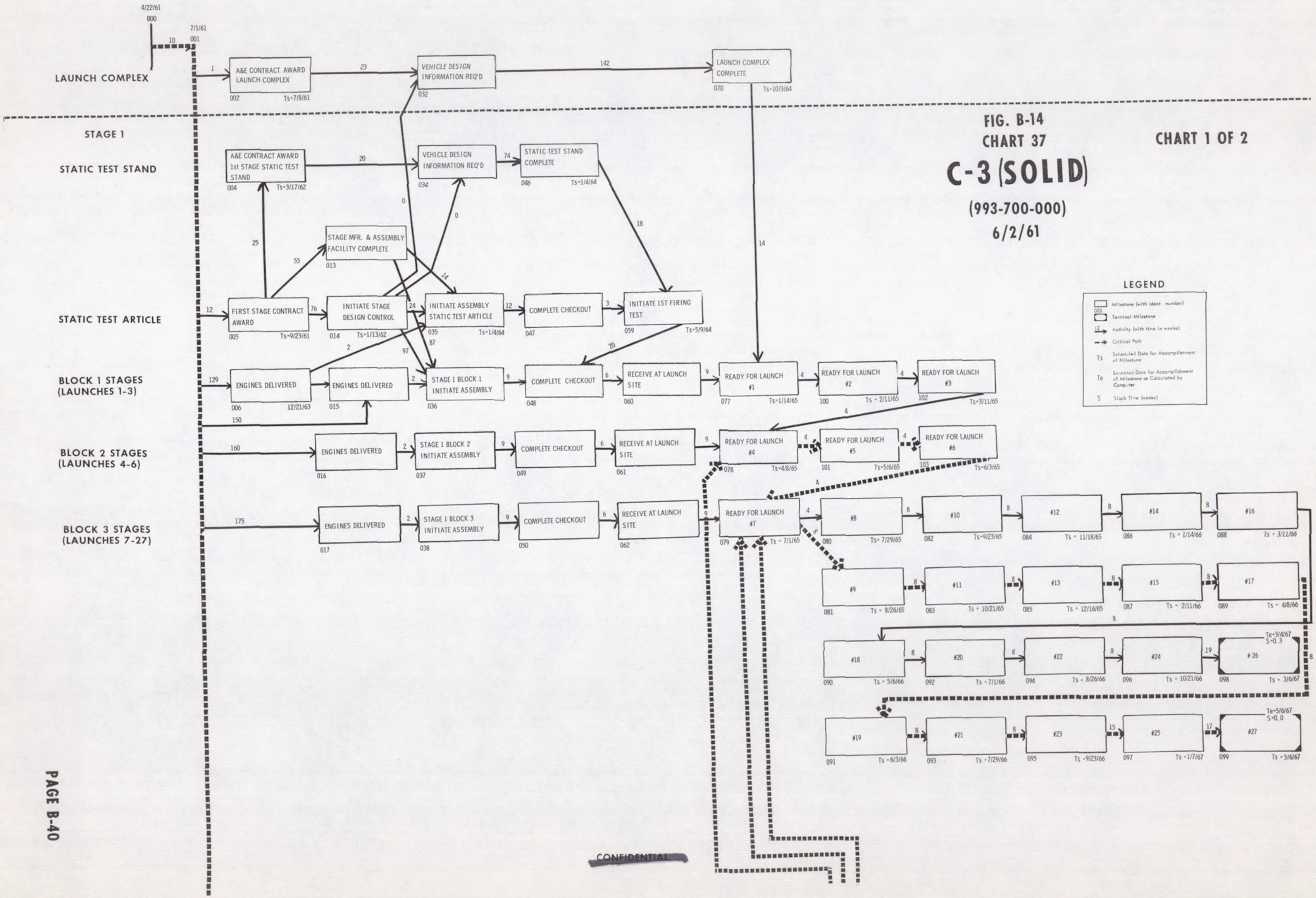
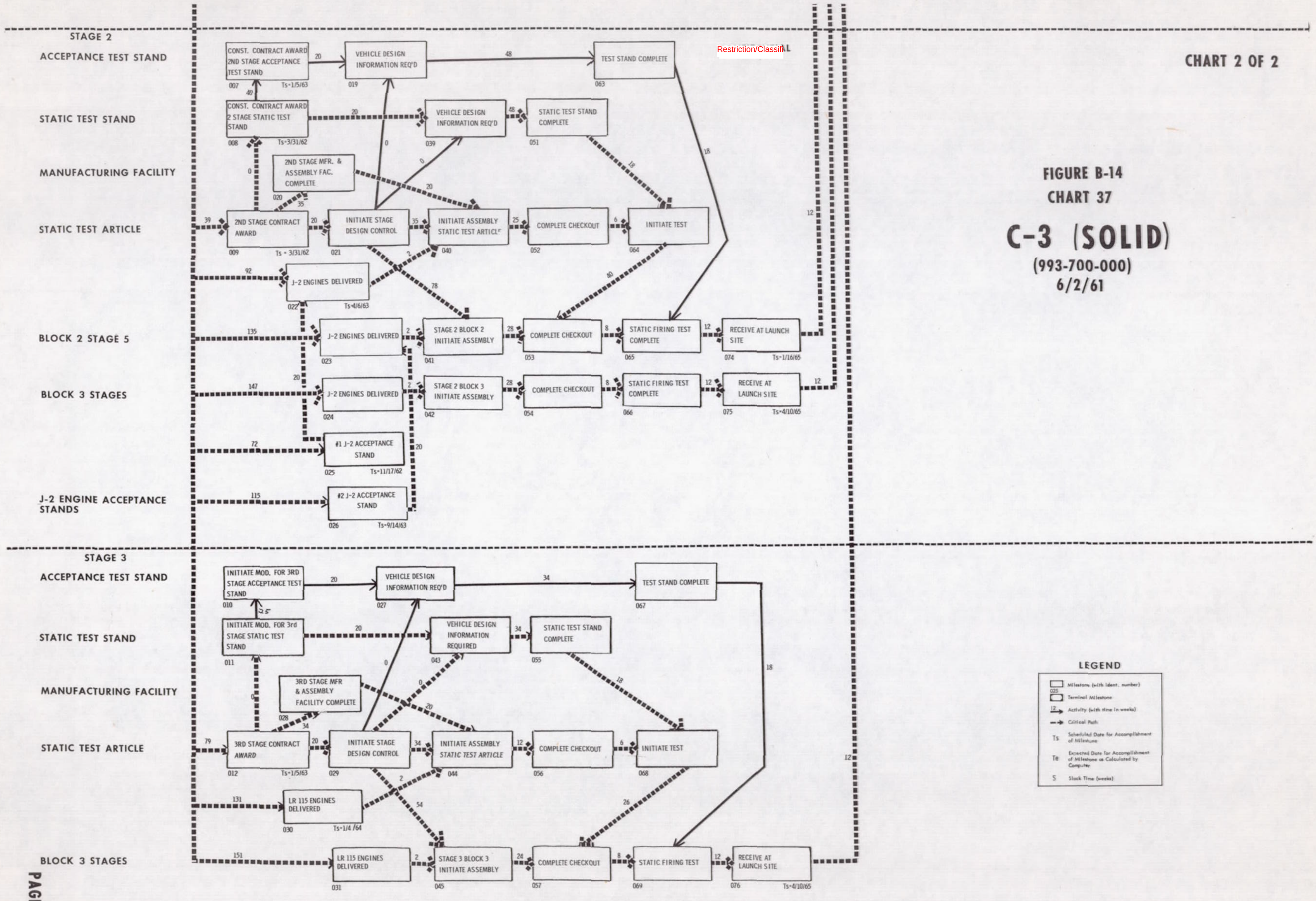


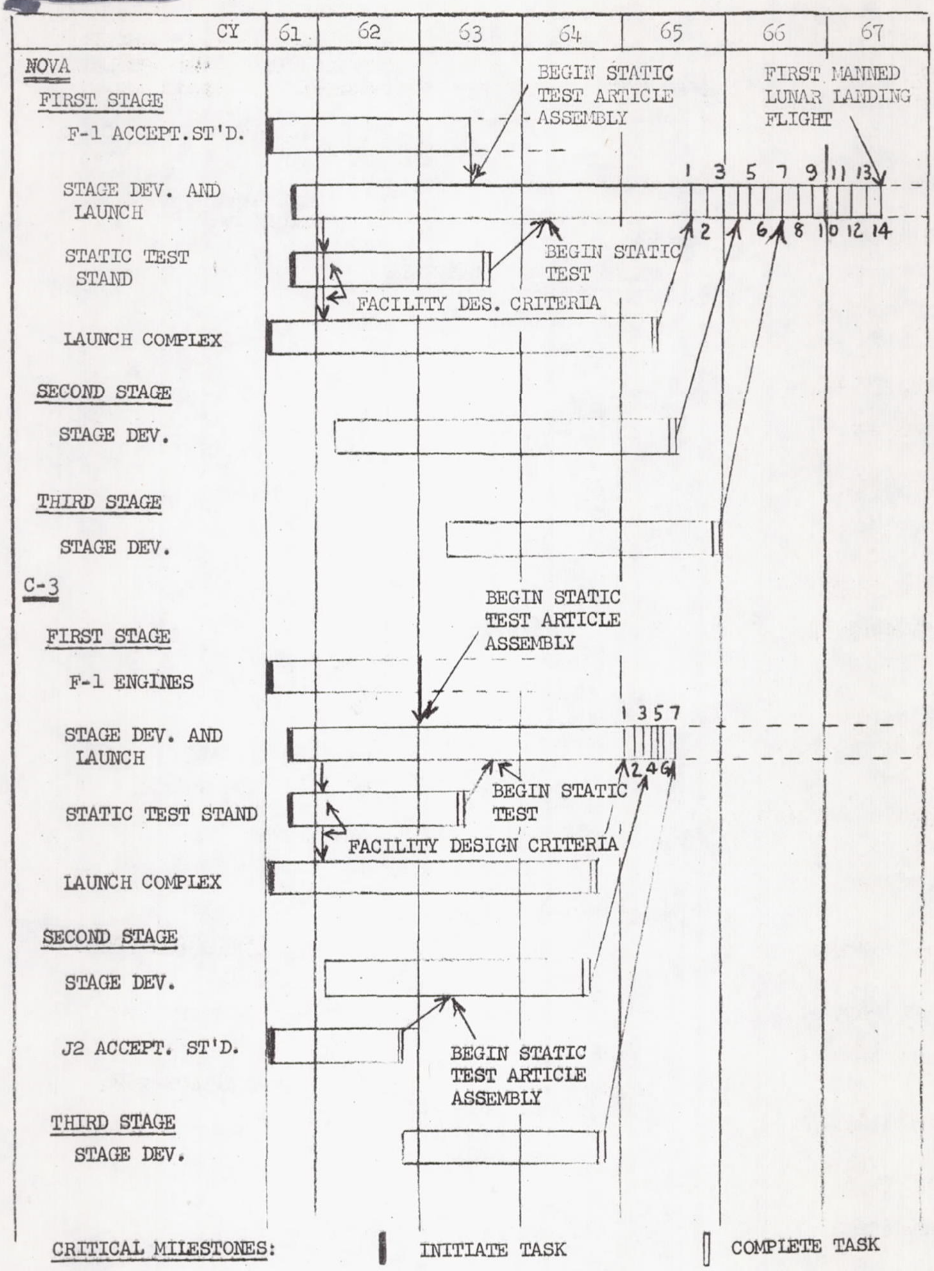
FIG. B-14
CHART 37
CHART 1 OF 2
C-3 (SOLID)
(993-700-000)
6/2/61

FIGURE B-14
CHART 37

C-3 (SOLID)

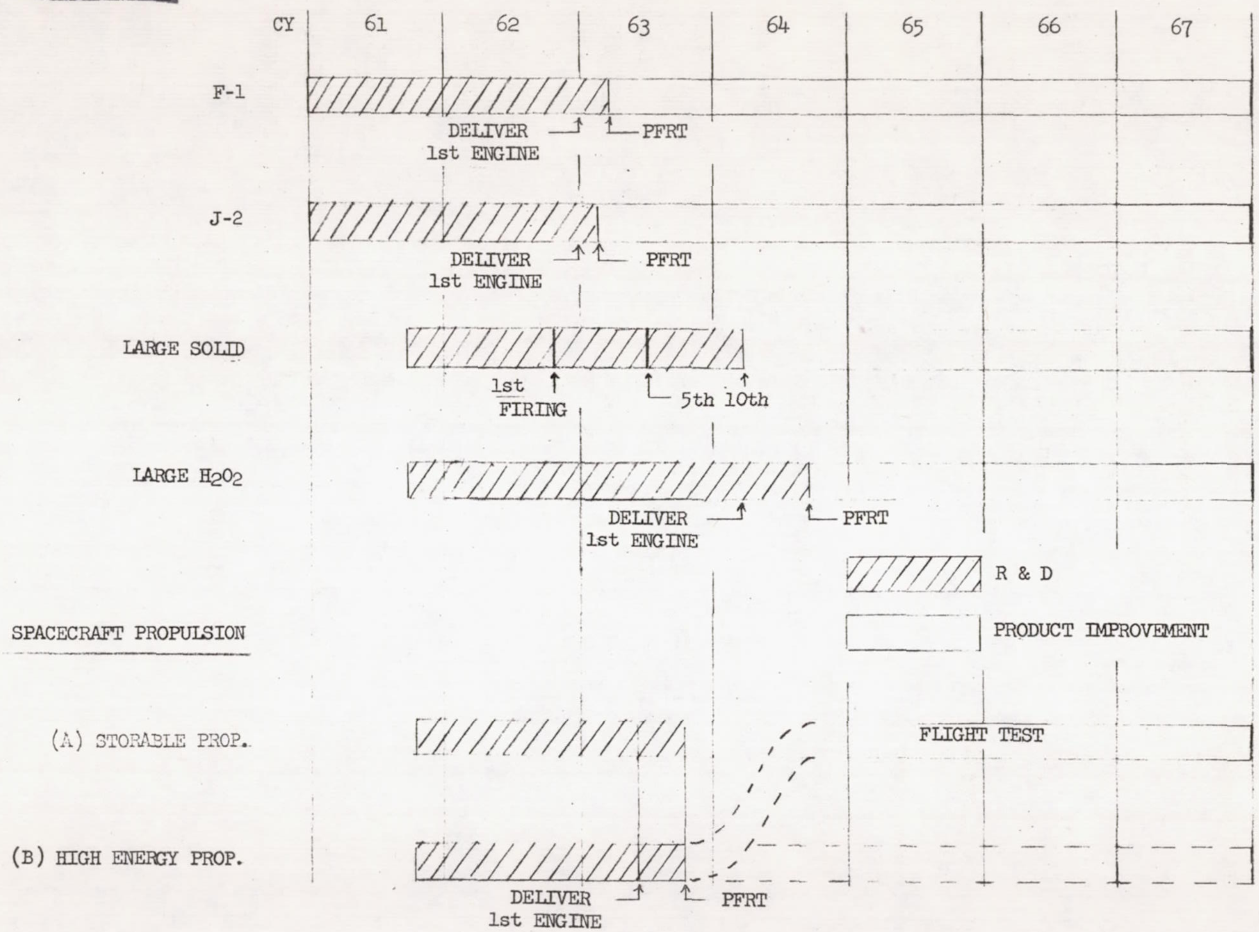
(993-700-000)
6/2/61





LIQUID VEHICLE DEVELOPMENT SCHEDULE

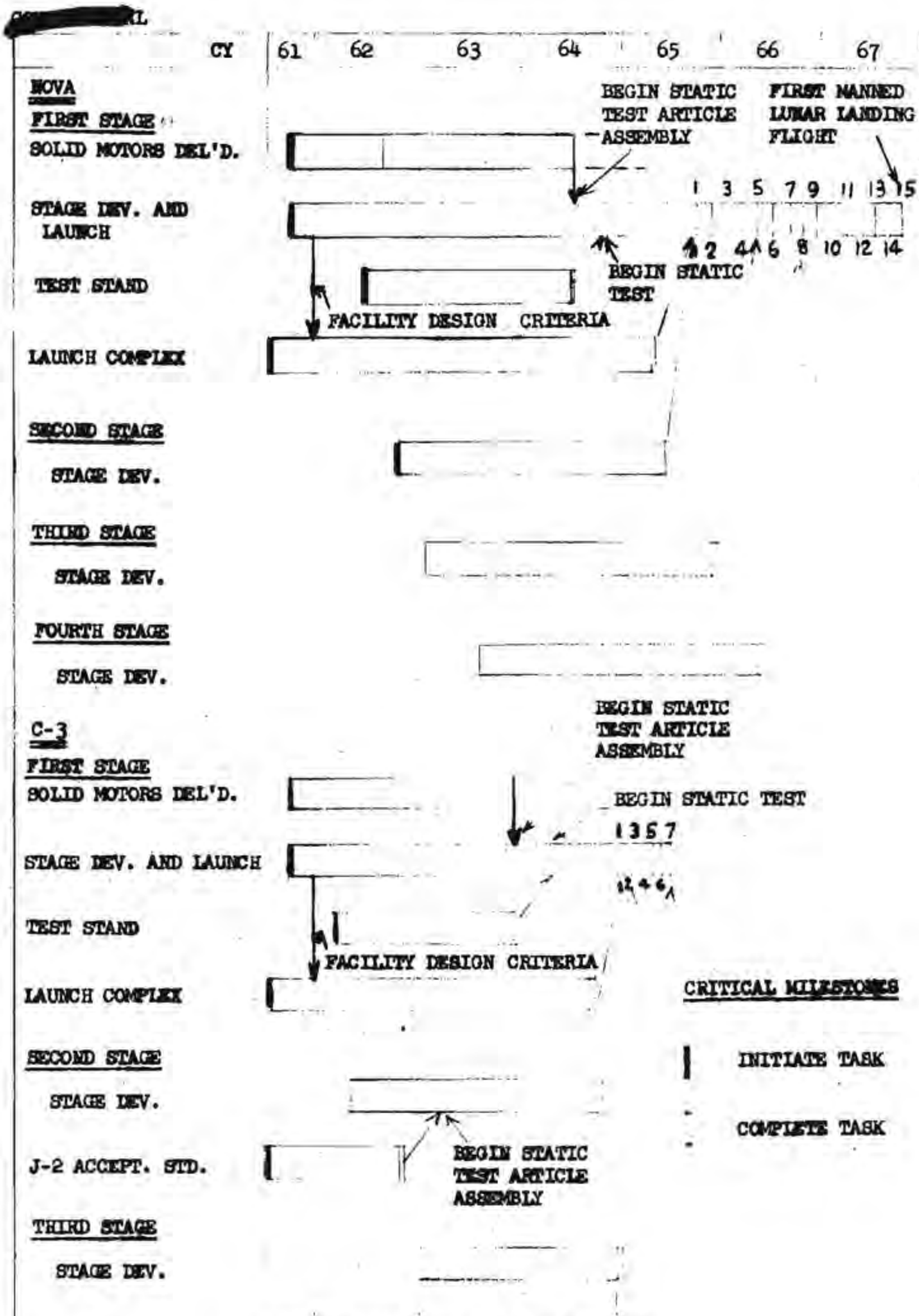
FIGURE B-15



ENGINE DEVELOPMENT SCHEDULE

FIGURE B-17

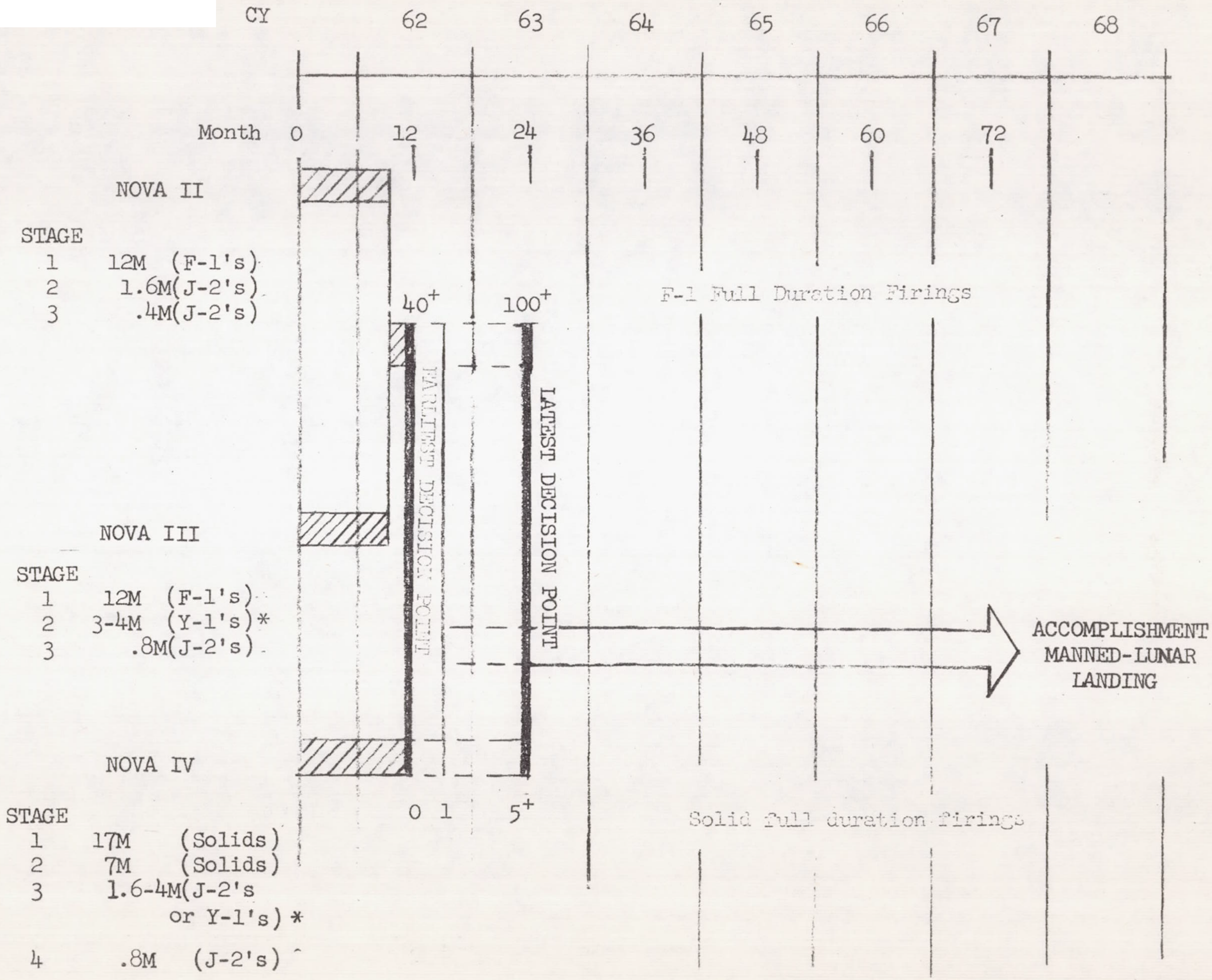
[redacted]



SOLID VEHICLE DEVELOPMENT SCHEDULE

FIGURE B-16

[redacted]



* Large H_2 - O_2 engine

NOVA VEHICLE DECISION POINTS

FIGURE B - 18

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-200-000	START APRIL 22 1961	0/00/00	0/00/00			1.4
993-200-001	PROJECT GO-AHEAD AUTHORIZED	7/01/61	7/11/61	7/01/61		1.4
993-200-005	1ST STAGE CONTRACT AWARD	9/23/61	10/03/61	9/23/61		1.4
993-200-014	1ST STAGE PREL VEHICLE DESIGN INFO	1/13/62	1/23/62	1/13/62		1.4
993-200-027	STAGE 1 VEHICLE DESIGN INFO REQUIRED	1/13/62	1/23/62			1.4
993-200-071	LAUNCH COMPLEX COMPLETE	5/08/65	5/18/65	5/08/65		1.4
993-200-078	READY FOR LAUNCH SER NO 1	9/11/65	9/21/65	9/19/65		1.4
993-200-091	READY FOR LAUNCH SER NO 2	11/06/65	11/16/65	11/14/65		1.4
993-200-093	READY FOR LAUNCH SER NO 3	1/01/66	1/11/66	1/10/66		1.4
993-200-079	READY FOR LAUNCH SER NO 4	2/26/66	3/08/66	3/07/66		1.4
993-200-092	READY FOR LAUNCH SER NO 5	4/23/66	5/03/66	5/02/66		1.4
993-200-094	READY FOR LAUNCH SER NO 6	6/18/66	6/28/66	6/27/66		1.4
993-200-080	READY FOR LAUNCH SER NO 7	8/13/66	8/23/66	8/22/66		1.4
993-200-081	READY FOR LAUNCH SER NO 8	10/01/66	10/11/66	9/10/66		1.4
993-200-082	READY FOR LAUNCH SER NO 9	11/19/66	11/29/66	11/28/66		1.4
993-200-083	READY FOR LAUNCH SER NO 10	1/07/67	1/17/67	1/17/67		1.4
993-200-084	READY FOR LAUNCH SER NO 11	2/25/67	3/07/67	3/07/67		1.4
993-200-085	READY FOR LAUNCH SER NO 12	4/15/67	4/25/67	4/25/67		1.4
993-200-086	READY FOR LAUNCH SER NO 13	6/03/67	6/13/67	6/13/67		1.4
993-200-088	READY FOR LAUNCH SER NO 15	7/22/67	8/01/67	8/01/67		1.4
993-200-087	READY FOR LAUNCH SER NO 14	7/22/67	8/01/67	8/01/67		1.4
993-200-090	READY FOR LAUNCH SER NO 17	11/25/67	12/05/67	12/05/67		1.4
993-200-089	READY FOR LAUNCH SER NO 16	11/25/67	12/05/67	12/05/67		1.4
993-200-002	LAUNCH COMPLEX A&E CONTRACT AWARD	7/08/61	8/15/61	7/08/61		5.4
993-200-006	F-1 ENGINES DELIVERED	6/22/63	8/06/63			6.4

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-200-030	INITIATE ASSEMBLY OF STATIC TEST ARTICLE	7/06/63	8/20/63	7/06/63		6.4
993-200-048	DEL STAGE 1 STATIC TST ART TO TEST STAND	2/22/64	4/07/64			6.4
993-200-060	STAGE 1 STATIC TEST ARTICLE 1ST FIRING	4/04/64	5/19/64	4/04/64		6.4
993-200-049	BLOCK 1 STAGE C O COMPLETE	2/13/65	3/30/65			6.4
993-200-061	STAGE 1 BLOCK 1 RECEIVE AT ACCEPT STAND	3/27/65	5/11/65			6.4
993-200-072	STAGE 1 BLOCK 1 ACCEPT FIRING TEST COMPLETE	7/10/65	8/24/65			6.4
993-200-008	2ND STAGE STATIC TEST STAND A&E CONT AWD	3/10/62	6/12/62	3/10/62		13.4
993-200-009	2ND STAGE CONTRACT AWARD	3/10/62	6/12/62	3/10/62		13.4
993-200-035	STAGE 2 VEHICLE DESIGN INFO REQUIRED	7/28/62	10/30/62			13.4
993-200-022	STAGE 2 STATIC ARTICLE PREL VEH DESIGN INFO	7/28/62	10/30/62			13.4
993-200-013	1ST STAGE MFG & ASSEM FAC COMPLETE	10/13/62	1/15/63			13.4
993-200-003	1ST STAGE ACCEPT TEST STAND A&E CONT AWD	12/29/62	4/02/63	12/29/62		13.4
993-200-018	NOS 1 2 &3 F-1 ACCEPT STANDS COMPLETE	2/23/63	5/28/63	2/23/63		13.4
993-200-021	STAGE 2 MFG & ASSEM FAC COMPLETE	2/23/63	5/28/63			13.4
993-200-012	3RD STAGE CONTRACT AWARD	4/06/63	7/09/63	4/06/63		13.4
993-200-011	3RD STAGE STATIC TEST STAND A&E CONT AWD	4/06/63	7/09/63	4/06/63		13.4
993-200-028	STAGE 1 VEHICLE DESIGN INFO REQUIRED	5/18/63	8/20/63			13.4
993-200-023	STAGE 2 STATIC ARTICLE J-2 ENGINES DELIVERED	8/10/63	11/12/63	8/10/63		13.4
993-200-036	INITIATE ASSEMBLY OF STATIC TEST ARTICLE	8/24/63	11/26/63			13.4
993-200-042	STAGE 3 VEHICLE DESIGN INFO REQUIRED	8/24/63	11/26/63			13.4
993-200-043	STAGE 3 PREL VEHICLE DESIGN INFO	8/24/63	11/26/63			13.4
993-200-019	NOS 4 & 5 F-1 ACCEPT STANDS COMPLETE	9/28/63	12/31/63			13.4
993-200-025	STAGE 3 MFG & ASSEMBLY FAC COMPLETE	12/07/63	3/10/64			13.4
993-200-052	STAGE 2 STATIC TEST STAND COMPLETE	12/28/63	3/31/64			13.4
993-200-015	F-1 ENGINES DELIVERED BLOCK 1	3/07/64	6/09/64			13.4

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-200-031	STAGE 1 BLOCK 1 INITIATE ASSEMBLY	3/21/64	6/23/64			13.4
993-200-053	STAGE 2 STATIC TEST ART C O COMPLETE	3/21/64	6/23/64			13.4
993-200-026	STAGE 3 STATIC TEST J-2 ENGINES DELIVERED	4/11/64	7/14/64			13.4
993-200-044	STAGE 3 INITIATE ASSEM OF STATIC TEST ARTICLE	4/25/64	7/28/64			13.4
993-200-065	STAGE 2 STATIC TEST ARTICLE START TEST	5/02/64	8/04/64			13.4
993-200-056	STAGE 3 STATIC TEST STAND COMPLETE	7/25/64	10/27/64			13.4
993-200-037	STAGE 2 STATIC TEST J-2 ENGINES DELIVERED	8/15/64	11/17/64			13.4
993-200-038	STAGE 2 BLOCK 1 INITIATE ASSEMBLY	8/29/64	12/01/64			13.4
993-200-057	STAGE 3 STATIC TESARTICLE C O COMPLETE	10/17/64	1/19/65			13.4
993-200-016	F-1 ENGINES DELIVERED BLOCK 2	11/14/64	2/16/65			13.4
993-200-032	STAGE 1 BLOCK 2 INITIATE ASSEMBLY	11/28/64	3/02/65			13.4
993-200-069	STAGE 3 STATIC TEST ARTICLE START TEST	11/28/64	3/02/65			13.4
993-200-034	F-1 ENGINES DELIVERED	12/12/64	3/16/65			13.4
993-200-059	STAGE 1 ACCEPTANCE TEST STAND COMPLETE	1/16/65	4/20/65	1/16/65		13.4
993-200-045	STAGE 3 J-2 ENGINES DELIVERED	1/23/65	4/27/65			13.4
993-200-046	STAGE 3 BLOCK 3 INITIATE ASSEMBLY	2/06/65	5/11/65			13.4
993-200-039	J-2ENGINES DELIVERED	2/27/65	6/01/65			13.4
993-200-040	STAGE 2 BLOCK 3 INITIATE ASSEMBLY	3/13/65	6/15/65			13.4
993-200-054	STAGE 2 BLOCK 2 C O COMPLETE	5/01/65	8/03/65			13.4
993-200-017	F-1 ENGINES DELIVERED BLOCK 3	5/15/65	8/17/65			13.4
993-200-033	STAGE 1 BLOCK 3 INITIATE ASSEMBLY	5/29/65	8/31/65			13.4
993-200-050	BLOCK 2 STAGE C O COMPLETE	7/10/65	10/12/65			13.4
993-200-066	STAGE 2 BLOCK 2 STATIC FIRING TEST COMPL	7/10/65	10/12/65			13.4
993-200-062	STAGE 1 BLOCK 2 RECEIVE AT ACCEPT STAND	8/21/65	11/23/65			13.4
993-200-075	STAGE 2 BLOCK 2 RECEIVE AT LAUNCH SITE	9/04/65	12/07/65	9/04/65		13.4

CONFIDENTIAL

Table V

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-200-055	STAGE 2 BLOCK 3 C O COMPLETE	10/09/65	1/11/66			13.4
993-200-058	STAGE 3 BLOCK 3 C O COMPLETE	10/09/65	1/11/66			13.4
993-200-073	STAGE 1 BLOCK 2 ACCEPT FIRING TEST COMPLETE	11/13/65	2/15/66			13.4
993-200-067	STAGE 2 BLOCK 3 STATIC FIRING TEST COMPL	12/04/65	3/08/66			13.4
993-200-070	STAGE 3 BLOCK 3 STATIC FIRING TEST	12/04/65	3/08/66			13.4
993-200-051	BLOCK 3 STAGE C O COMPLETE	12/25/65	3/29/66			13.4
993-200-063	STAGE 1 BLOCK O RECEIVE AT ACCEPT STAND	2/05/66	5/10/66			13.4
993-200-076	STAGE 2 BLOCK 3 RECEIVE AT LAUNCH SITE	2/26/66	5/31/66	2/26/66		13.4
993-200-077	STAGE 3 BLOCK 3 RECEIVE AT LAUNCH SITE	2/26/66	5/31/66	2/26/66		13.4
993-200-074	STAGE 1 BLOCK 3 ACCEPT FIRING TEST COMPLETE	4/30/66	8/02/66			13.4
993-200-010	3RD STAGE ACCEPT TEST STAND A&E CONT AWD	4/04/64	7/14/64	4/04/64		14.4
993-200-024	STAGE 3 VEHICLE DESIGN INFO REQUIRED	8/22/64	12/01/64			14.4
993-200-068	STAGE 3 ACCEPTANCE TEST STAND COMPLETE	7/24/65	11/02/65			14.4
993-200-007	2ND STAGE ACCEPT TEST STAND A&E CONT AWD	5/04/63	8/20/63	5/04/63		15.4
993-200-020	STAGE 2 VEHICLE DESIGN INFO REQUIRED	9/21/63	1/07/64			15.4
993-200-041	NOS 3 4 &5 J-2 ACCEPTANCE STANDS COMPLETE	5/02/64	8/18/64	5/02/64		15.4
993-200-064	STAGE 2 TEST STAND COMPLETE	2/20/65	6/08/65			15.4
993-200-004	1ST STAGE STATIC TEST STAND A&E CONT AWD	9/23/61	1/23/62	9/23/61		17.4
993-200-029	STAGE 1 VEHICLE DESIGN INFO REQUIRED	1/13/62	5/15/62			17.4
993-200-047	STAGE 1 STATIC TEST STAND COMPLETE	9/14/63	1/14/64	9/14/63		17.4

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-600-099	STAGE 1 BLOCK 3 READY FOR LAUNCH 27	5/06/67	5/06/67	5/06/67		0.0
993-600-000	START APRIL 22 1961	0/00/00	0/00/00			0.0
993-600-001	PROJECT GO-AHEAD AUTHORIZED	7/01/61	7/01/61	7/01/61		0.0
993-600-005	STAGE1 STATIC TEST ARTICLE CONTRACT AWARD	9/23/61	9/23/61	9/23/61		0.0
993-600-013	STAGE1 MFG & ASSEM FACILITY COMP	4/21/62	4/21/62			0.0
993-600-036	STAGE1 BLOCK1 INITIATE ASSEMBLY	12/21/63	12/21/63			0.0
993-600-037	STAGE1 BLOCK2 INITIATE ASSEMBLY	3/14/64	3/14/64			0.0
993-600-049	STAGE1 BLOCK2 CHECKOUT COMPLETE	9/26/64	9/26/64			0.0
993-600-061	STAGE 1 BLOCK 2 RECEIVE AT ACCEPTANCE STAND	10/10/64	10/10/64			0.0
993-600-072	STAGE 1 BLOCK 2 ACCEPTANCE FIRING TEST COMPLETE	11/21/64	11/21/64			0.0
993-600-078	STAGE 1 BLOCK 2 READY FOR LAUNCH 4	4/10/65	4/10/65	4/08/65		0.0
993-600-101	STAGE 1 BLOCK 2 READY FOR LAUNCH 5	5/08/65	5/08/65	5/06/65		0.0
993-600-103	STAGE 1 BLOCK 2 READY FOR LAUNCH 6	6/05/65	6/05/65	6/03/65		0.0
993-600-079	STAGE 1 BLOCK 3 READY FOR LAUNCH 7	7/03/65	7/03/65	7/01/65		0.0
993-600-081	STAGE 1 BLOCK 3 READY FOR LAUNCH 9	8/28/65	8/28/65	8/26/65		0.0
993-600-083	STAGE 1 BLOCK 3 READY FOR LAUNCH 11	10/23/65	10/23/65	10/21/65		0.0
993-600-085	STAGE 1 BLOCK 3 READY FOR LAUNCH 13	12/18/65	12/18/65	12/16/65		0.0
993-600-087	STAGE 1 BLOCK 3 READY FOR LAUNCH 15	2/12/66	2/12/66	2/11/66		0.0
993-600-089	STAGE 1 BLOCK 3 READY FOR LAUNCH 17	4/09/66	4/09/66	4/08/66		0.0
993-600-091	STAGE 1 BLOCK 3 READY FOR LAUNCH 19	6/04/66	6/04/66	6/03/66		0.0
993-600-093	STAGE 1 BLOCK 3 READY FOR LAUNCH 21	7/30/66	7/30/66	7/29/66		0.0
993-600-095	STAGE 1 BLOCK 3 READY FOR LAUNCH 23	9/24/66	9/24/66	9/23/66		0.0
993-600-097	STAGE 1 BLOCK 3 READY FOR LAUNCH 25	1/07/67	1/07/67	1/07/67		0.0
993-600-080	STAGE 1 BLOCK 3 READY FOR LAUNCH 8	7/31/65	8/02/65	7/29/65		0.3
993-600-082	STAGE 1 BLOCK 3 READY FOR LAUNCH 10	9/25/65	9/27/65	9/23/65		0.3

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-600-084	STAGE 1 BLOCK 3 READY FOR LAUNCH 12	11/20/65	11/22/65	11/18/65		0.3
993-600-086	STAGE 1 BLOCK 3 READY FOR LAUNCH 14	1/15/66	1/17/66	1/14/66		0.3
993-600-088	STAGE 1 BLOCK 3 READY FOR LAUNCH 16	3/12/66	3/14/66	3/11/66		0.3
993-600-090	STAGE 1 BLOCK 3 READY FOR LAUNCH 18	5/07/66	5/09/66	5/06/66		0.3
993-600-092	STAGE 1 BLOCK 3 READY FOR LAUNCH 20	7/02/66	7/04/66	7/01/66		0.3
993-600-094	STAGE 1 BLOCK 3 READY FOR LAUNCH 22	8/27/66	8/29/66	8/26/66		0.3
993-600-096	STAGE 1 BLOCK 3 READY FOR LAUNCH 24	10/22/66	10/24/66	10/21/66		0.3
993-600-098	STAGE 1 BLOCK 3 READY FOR LAUNCH 26	3/04/67	3/06/67	3/06/67		0.3
993-600-004	STAGE1 STATIC TEST STAND A&E CONT AWARD	9/23/61	9/30/61	9/23/61		1.0
993-600-014	STAGE1 STATIC TEST ARTICLE INITIATE DESIGN CONTR	1/13/62	1/20/62	1/13/62		1.0
993-600-032	LAUNCH COMPLEX VEHICLE DESIGN INFORMATION REQD	1/13/62	1/20/62			1.0
993-600-034	STAGE1 STATIC TEST STAND VEHICL DESIGN INFO REQD	1/13/62	1/20/62			1.0
993-600-046	STAGE1 STATIC TEST STAND COMPLETE	6/15/63	6/22/63	6/15/63		1.0
993-600-059	STAGE1 STATIC TEST ARTICLE INITIATE 1ST FIRE TES	10/19/63	10/26/63	10/19/63		1.0
993-600-048	STAGE1 BLOCK1 CHECKOUT COMPLETE	7/11/64	7/18/64			1.0
993-600-060	STAGE1 BLOCK1 RECEIVE AT ACCEPTANCE STAND	7/25/64	8/01/64			1.0
993-600-071	STAGE1 BLOCK1 ACCEPT FIRING TEST COMPLETE	9/05/64	9/12/64			1.0
993-600-070	LAUNCH COMPLEX COMPLETE	10/03/64	10/10/64	10/03/64		1.0
993-600-077	STAGE1 BLOCK1 READY FOR LAUNCH 1	1/09/65	1/16/65	1/14/65		1.0
993-600-100	STAGE1 BLOCK1 READY FOR LAUNCH 2	2/06/65	2/13/65	2/11/65		1.0
993-600-102	STAGE1 BLOCK1 READY FOR LAUNCH 3	3/06/65	3/13/65	3/11/65		1.0
993-600-015	STAGE1 BLOCK1 F-1 ENGINES DELIVERED	11/23/63	12/07/63			2.0
993-600-009	STAGE 2 STATIC TEST ARTICLE CONTACT AWARD	2/03/62	3/03/62	2/03/62		4.0
993-600-021	STAGE 2 STATIC TEST ARTICLE INITIATE DESIGN CONT	6/23/62	7/21/62			4.0
[illegible]-600-020	STAGE 2 MFG & ASSEM FACILITY COMPLETE	[illegible]/03/62	12/01/62			

CONF[illegible]

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-600-040	STAGE 2 STATIC TEST ARTICLE INITIATE ASSEMBLY	3/23/63	4/20/63			4.0
993-600-052	STAGE 2 STATIC TEST ARTICLE CHECKOUT COMPLETE	9/14/63	10/12/63			4.0
993-600-064	STAGE 2 STATIC TEST ARTICLE INITIATE TEST	10/26/63	11/23/63			4.0
993-600-016	STAGE1 BLOCK2 F-1 ENGINES DELIVERED	2/01/64	2/29/64			4.0
993-600-038	STAGE 1 BLOCK 3 INITIATE ASSEMBLY	6/06/64	7/04/64			4.0
993-600-053	STAGE 2 BLOCK 2 CHECKOUT COMPLETE	8/01/64	8/29/64			4.0
993-600-065	STAGE 2 BLOCK 2 STATIC FIRING TEST COMPLETE	9/26/64	10/24/64			4.0
993-600-050	STAGE 1 BLOCK 3 CHECKOUT COMPLETE	11/21/64	12/19/64			4.0
993-600-062	STAGE 1 BLOCK 3 RECEIVE AT ACCEPTANCE STAND	12/05/64	1/02/65			4.0
993-600-074	STAGE 2 BLOCK 2 RECEIVE AT LAUNCH SITE	12/19/64	1/16/65	12/19/64		4.0
993-600-073	STAGE 1 BLOCK 3 ACCEPTANCE FIRING TEST COMPLETED	1/16/65	2/13/65			4.0
993-600-002	LAUNCH COMPLEX A&E CONTRACT AWARD	7/08/61	8/12/61	7/08/61		5.0
993-600-008	STAGE 2 STATIC TEST STAND CONST CONT AWARD	2/03/62	3/31/62	2/03/62		8.0
993-600-039	STAGE 2 STATIC TEST STAND VEHICLE INFO REQ D	6/23/62	8/18/62			8.0
993-600-022	STAGE 2 STATIC TEST ARTICLE J-2 ENGINES DELIVERE	2/16/63	4/13/63	2/16/63		8.0
993-600-051	STAGE 2 STATIC TEST STAND COMPLETE	5/25/63	7/20/63			8.0
993-600-041	STAGE 2 BLOCK 2 INITIATE ASSEMBLY	12/21/63	2/15/64			8.0
993-600-042	STAGE 2 BLOCK 3 INITIATE ASSEMBLY	3/14/64	5/09/64			8.0
993-600-017	STAGE 1 BLOCK 3 F-1 ENGINES DELIVERED	4/25/64	6/20/64			8.0
993-600-054	STAGE 2 BLOCK 3 CHECKOUT COMPLETE	9/26/64	11/21/64			8.0
993-600-066	STAGE 2 BLOCK 3 STATIC FIRING TEST COMPLETE	11/21/64	1/16/65			8.0
993-600-075	STAGE 2 BLOCK 3 RECEIVE AT LAUNCH SITE	2/13/65	4/10/65	2/13/65		8.0
993-600-011	STAGE 3 STATIC TEST TEST STAND INITIATE MODS	11/03/62	1/05/63			9.0
993-600-012	STAGE 3 STATIC TEST AETICLE CONTRACT AWARD	11/03/62	1/05/63	11/03/62		9.0
993-600-043	STAGE 3 STATIC TEST STAND VEHICLE DESIGN INFO RE	3/23/63	5/25/63			9.0

CONFIDENTIAL

CONFIDENTIAL

[illegible] S Y S T E M

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-600-029	STAGE 3 STATIC TEST ARTICLE INITIATE DESIGN CONT	3/23/63	5/25/63			9.0
993-600-028	STAGE 3 MFG & ASSBY FACILITY COMPLETE	6/29/63	8/31/63			9.0
993-600-018	F-1 ENGINE ACCEPTANCE STANDS COMPLETE	9/14/63	11/16/63	9/14/63		9.0
993-600-044	STAGE 3 STATIC TEST ARTICLE INITIATE ASSEMBLY	11/16/63	1/18/64			9.0
993-600-055	STAGE 3 STATIC TEST STAND COMPLETE	11/16/63	1/18/64			9.0
993-600-056	STAGE 3 STATIC TEST ARTICLE CHECKOUT COMPLETE	2/08/64	4/11/64			9.0
993-600-068	STAGE 3 STATIC TEST ARTICLE INITIATE TEST	3/21/64	5/23/64			9.0
993-600-045	STAGE 3 BLOCK 3 INITIATE ASSEMBLY	4/04/64	6/06/64			9.0
993-600-057	STAGE 3 BLOCK 3 CHECKOUT COMPLETE	9/19/64	11/21/64			9.0
993-600-069	STAGE 3 BLOCK 3 STATIC FIRING TEST	11/14/64	1/16/65			9.0
993-600-076	STAGE 3 BLOCK 3 RECEIVE AT LAUNCH SITE	2/06/65	4/10/65	2/05/65		9.0
993-600-026	STAGE 2 J-2 ACCEPTANCE STAND 2 COMPLETE	7/06/63	9/14/63	7/06/63		10.0
993-600-023	STAGE 2 BLOCK 2 J-2 ENGINES DELIVERED	11/23/63	2/01/64			10.0
993-600-024	STAGE 2 BLOCK 3 J-2 ENGINES DELIVERED	2/15/64	4/25/64			10.0
993-600-025	STAGE 2 J-2 ACCEPTANCE STAND 1 COMPLETE	9/08/62	11/24/62	9/08/62		11.0
993-600-030	STAGE 3 STATIC TEST ARTICLE LR-115 ENGINES DELIV	10/19/63	1/04/64	10/19/63		11.0
993-600-031	STAGE 3 BLOCK 3 LR-115 ENGINES DELIVERED	3/07/64	5/23/64			11.0
993-600-006	STAGE1 STATIC TEST ARTICLE F-1 ENGINES DELIVERED	12/29/62	5/25/63	12/29/62		21.0
993-600-035	STAGE1 STATIC TEST ARTICLE INITIATE ASSEMBLY	1/05/63	6/01/63	1/05/63		21.0
993-600-047	STAGE1 STATIC TEST ARTICLE CECKOUT COMPLETE	4/20/63	9/14/63			21.0
993-600-003	STAGE1 ACCEPT TEST STAND A&E CONT AWARD	2/10/62	7/21/62	2/10/62		23.0
993-600-033	STAGE1 ACCEPT TEST STAND VEHICLEDESIGN INFO REQD	6/30/62	12/08/62			23.0
993-600-010	STAGE 3 ACCEPTANCE TEST STAND INITIATE MODS	3/23/63	8/31/63			23.0
993-600-027	STAGE 3 ACCEPTANCE TEST STAND VEHICLE DESIGN INF	8/10/63	1/18/64			23.0
993-600-058	STAGE1 ACCEPT TEST STAND COMPLETE	11/30/63	5/09/64	[illegible]		[illegible]

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-600-067	STAGE 3 ACCEPTANCE TEST STAND COMPLETE	4/04/64	9/12/64			23.0
993-600-007	STAGE 2 ACCEPTANCE TEST STAND CONST CONT AWARD	9/01/62	3/02/63	9/01/62		26.0
993-600-019	STAGE 2 ACCEPTANCE TEST STAND VEHICLE INFO REQ D	1/19/63	7/20/63			26.0
993-600-063	STAGE 2 ACCEPTANCE TEST STAND COMPLETE	12/21/63	6/20/64			26.0

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-400-000	START NOVA 4 LAUNCH COMPLEX	0/00/00	0/00/00			- 10.6
993-400-001	INITIATE PROJECT	7/01/61	4/18/61	7/01/61		- 10.6
993-400-102	STAGE 4 3 ACCEPTANCE STANDS READY	6/12/65	3/30/65	6/12/65		- 10.6
993-400-013	J-2 ENGINES DELIVERED FOR STAGE 4	7/24/65	5/11/65			- 10.6
993-400-034	START ASSY BLOCK 3 STAGE 4	8/07/65	5/25/65			- 10.6
993-400-083	STAGE 4 BLOCK 3 STAGES CHECKOUT COMPLETE	4/09/66	1/25/66			- 10.6
993-400-084	STAGE 4 BLOCK 3 STATIC FIRING TEST	6/04/66	3/22/66			- 10.6
993-400-055	STAGE 1 BLOCK 3 STAGES AT LAUNCH SITE	8/27/66	6/14/66			- 10.6
993-400-070	COMPL ASSY & CHECKOUT STAGE 1 BLOCK 3 STAGES	10/22/66	8/09/66			- 10.6
993-400-079	STAGE 1 BLOCK 3 SERIAL 8 READY FOR LAUNCH	11/05/66	8/23/66	8/22/66		- 10.6
993-400-088	STAGE 1 BLOCK 3 SERIAL 10 READY FOR LAUNCH	2/11/67	11/29/66	11/28/66		- 10.6
993-400-092	STAGE 1 BLOCK 3 SERIAL 12 READY FOR LAUNCH	5/20/67	3/07/67	3/07/67		- 10.6
993-400-097	STAGE 1 BLOCK 3 SERIAL 16 READY FOR LAUNCH	10/14/67	8/01/67	8/01/67		- 10.6
993-400-004	CONTRACT FOR FIRST STAGE STATIC TEST ARTICLE	9/23/61	7/18/61	9/23/61		- 9.6
993-400-014	FIRST STAGE MFG & ASSY FACILITY COMPLETE	6/30/62	4/24/62			- 9.6
993-400-027	J-2 ENGINES DELIVERED FOR STATIC STAGE 3	4/18/64	2/11/64	4/18/64		- 9.6
993-400-048	START ASSY STAGE 3 STATIC TEST ARTICLE	5/02/64	2/25/64			- 9.6
993-400-062	STAGE 3 STATIC TEST ARTICLE CHECKOUT COMPLETE	10/24/64	8/18/64			- 9.6
993-400-073	START STAGE 3 STATIC TEST	12/05/64	9/29/64			- 9.6
993-400-038	START ASSY BLOCK 1 STAGE 1	4/03/65	1/26/65			- 9.6
993-400-053	STAGE 1 BLOCK 1 STAGES AT LAUNCH SITE	8/21/65	6/15/65			- 9.6
993-400-068	COMPL ASSY & CHECKOUT STAGE 1 BLOCK 1 STAGES	10/09/65	8/03/65			- 9.6
993-400-074	STAGE 3 BLOCK 2 STAGES CHECKOUT COMPLETE	10/16/65	8/10/65			- 9.6
993-400-077	STAGE 1 BLOCK 1 SERIAL 1 READY FOR LAUNCH	10/23/65	8/17/65	8/01/65		- 9.6
993-400-080	STAGE 3 STATIC TEST FIRING BLOCK 2 STAGES	12/11/65	10/05/65			- 9.6

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-400-085	STAGE 1 BLOCK 1 SERIAL 2 READY FOR LAUNCH	12/11/65	10/05/65	9/19/65		- 9.6
993-400-089	STAGE 1 BLOCK 1 SERIAL 3 READY FOR LAUNCH	1/29/66	11/23/65	11/14/65		- 9.6
993-400-054	STAGE 1 BLOCK 2 STAGES AT LAUNCH SITE	3/05/66	12/28/65			- 9.6
993-400-093	STAGE 1 BLOCK 1 SERIAL 4 READY FOR LAUNCH	3/19/66	1/11/66	1/10/65		- 9.6
993-400-069	COMPL ASSY & CHECKOUT STAGE 1 BLOCK 2 STAGES	4/30/66	2/22/66			- 9.6
993-400-078	STAGE 1 BLOCK 2 SERIAL 5 READY FOR LAUNCH	5/14/66	3/08/66	3/07/66		- 9.6
993-400-086	STAGE 1 BLOCK 2 SERIAL 6 READY FOR LAUNCH	7/09/66	5/03/66	5/02/66		- 9.6
993-400-090	STAGE 1 BLOCK 2 SERIAL 7 READY FOR LAUNCH	9/03/66	6/28/66	6/27/66		- 9.6
993-400-087	STAGE 1 BLOCK 3 SERIAL 9 READY FOR LAUNCH	12/24/66	11/08/66	9/10/66		- 6.6
993-400-091	STAGE 1 BLOCK 3 SERIAL 11 READY FOR LAUNCH	4/01/67	2/14/67	1/17/67		- 6.6
993-400-094	STAGE 1 BLOCK 3 SERIAL 13 READY FOR LAUNCH	7/08/67	5/23/67	4/25/67		- 6.6
993-400-095	STAGE 1 BLOCK 3 SERIAL 14 READY FOR LAUNCH	8/26/67	7/11/67	6/13/67		- 6.6
993-400-096	STAGE 1 BLOCK 3 SERIAL 15 READY FOR LAUNCH	10/14/67	8/29/67	8/01/67		- 6.6
993-400-098	STAGE 1 BLOCK 3 SERIAL 17 READY FOR LAUNCH	1/20/68	12/05/67	12/05/67		- 6.6
993-400-099	STAGE 1 BLOCK 3 SERIAL 18 READY FOR LAUNCH	1/20/68	12/05/67	12/05/67		- 6.6
993-400-008	CONTRACT FOR THIRD STAGE STATIC TEST STAND	2/02/63	12/25/62	2/02/63		- 5.6
993-400-009	CONTRACT FOR THIRD STAGE STATIC TEST ARTICLE	2/02/63	12/25/62	2/02/63		- 5.6
993-400-007	CONTRACT FOR ACCEPTANCE TEST STAND	3/21/64	2/11/64	3/21/64		- 5.6
993-400-025	STAGE 3 DESIGN INFO REQUIRED	8/08/64	6/30/64			- 5.6
993-400-021	STATIC STAGE 2 SOLID MOTORS DELIVERED	9/26/64	8/18/64			- 5.6
993-400-042	START STATIC TEST ARTICLE STAGE 2	10/10/64	9/01/64			- 5.6
993-400-101	STAGE 3 1 & 2 ACCEPTANCE STANDS READY	10/17/64	9/08/64	10/17/64		- 5.6
993-400-028	J-2 ENGINES DELIVERED FOR BLOCK 2 STAGE 3	1/02/65	11/24/64			- 5.6
993-400-057	STAGE 2 STATIC TEST ARTICLE CHECKOUT COMPLETE	1/02/65	11/24/64			- 5.6
993-400-049	START ASSY BLOCK 2 STAGE 3	1/16/65	12/08/64			- 5.6

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-400-071	START STAGE 2 STATIC TEST	1/23/65	12/15/64			- 5.6
993-400-022	BLOCK 1 STAGE 2 SOLID MOTORS DELIVERD	3/20/65	2/09/65			- 5.6
993-400-043	START ASSY BLOCK 1 STAGE 2	4/03/65	2/23/65			- 5.6
993-400-058	STAGE 2 BLOCK 1 STAGES READY TO SHIP	6/12/65	5/04/65	6/12/65		- 5.6
993-400-050	START ASSY BLOCK 3 STAGE 3	7/03/65	5/25/65			- 5.6
993-400-072	STAGE 3 TEST STAND COMPLETE	7/10/65	6/01/65			- 5.6
993-400-023	BLOCK 2 STAGE 2 SOLID MOTORS DELIVERED	10/09/65	8/31/65			- 5.6
993-400-044	START ASSY BLOCK 2 STAGE 2	10/23/65	9/14/65			- 5.6
993-400-059	STAGE 2 BLOCK 2 STAGES READY TO SHIP	12/25/65	11/16/65	12/25/65		- 5.6
993-400-075	STAGE 3 BLOCK 3 STAGES CHECKOUT COMPLETE	3/05/66	1/25/66			- 5.6
993-400-024	BLOCK 3 STAGE 2 SOLID MOTORS DELIVERED	3/26/66	2/15/66			- 5.6
993-400-045	START ASSY BLOCK 3 STAGE 2	4/09/66	3/01/66			- 5.6
993-400-081	STAGE 3 STATIC TEST FIRING BLOCK 3 STAGES	4/30/66	3/22/66			- 5.6
993-400-060	STAGE 2 BLOCK 3 STAGES READY TO SHIP	6/11/66	5/03/66	6/11/66		- 5.6
993-400-035	LAUNCH COMPLEX VEHICLE DESIGN INFO REQUIRED	1/13/62	12/19/61			- 3.6
993-400-015	START FIRST STG STATIC ARTICLE DESIGN CONTROL	1/13/62	12/19/61	1/13/62		- 3.6
993-400-012	CONTRACT FOR FOURTH STAGE STATIC TEST ARTICLE	8/17/63	7/23/63	8/17/63		- 3.6
993-400-011	INITIATE FOURTH STAGE STATIC TEST STAND MODS	8/17/63	7/23/63	8/17/63		- 3.6
993-400-032	START STATIC STAGE 4 DESIGN CONTROL	1/04/64	12/10/63			- 3.6
993-400-100	STAGE 4 STATIC STAND VEHICLE INFO REQUIRED	1/04/64	12/10/63			- 3.6
993-400-031	STAGE 4 MFG & ASSY FACILITIES COMPLETE	4/18/64	3/24/64			- 3.6
993-400-033	J-2 ENGINES DEL FOR STATIC STAGE 4	8/22/64	7/28/64			- 3.6
993-400-065	START ASSY STAGE 4 STATIC TEST ARTICLE	9/05/64	8/11/64			- 3.6
993-400-064	STAGE 4 STATIC TEST STAND COMPLETE	12/05/64	11/10/64			- 3.6
993-400-066	COMPLETE CHECKOUT STAGE 4 STATIC TEST ARTICLE	2/27/65	2/02/65			- 3.6

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-400-082	STAGE 4 STATIC TEST FIRING	4/10/65	3/16/65			- 3.6
993-400-076	LAUNCH COMPLEX COMPLETE	5/08/65	4/13/65	5/08/65		- 3.6
993-400-029	J-2 ENGINES DEL FOR BLOCK 3 STAGES	6/05/65	5/11/65			- 3.6
993-400-019	BLOCK 3 STAGE 1 SOLID MOTORS DELIVERED	2/05/66	1/11/66			- 3.6
993-400-040	START ASSY BLOCK 3 STAGE 1	2/19/66	1/25/66			- 3.6
993-400-010	INITIATE FOURTH STAGE ACCEPTANCE STAND MODS	8/15/64	7/28/64	8/15/64		- 2.6
993-400-030	STAGE 4 DESIGN INFO REQUIRED	1/02/65	12/15/64			- 2.6
993-400-063	STAGE 4 TEST STAND COMPLETE	12/04/65	11/16/65			- 2.6
993-400-003	A&E CONTRACT FOR FIRST STAGE STATIC TEST STAND	6/30/62	6/26/62	6/30/62		- 0.6
993-400-036	STAGE 1 VEHICLE DESIGN INFO REQUIRED	11/17/62	11/13/62			- 0.6
993-400-051	STAGE 1 TEST STAND COMPLETE	7/18/64	7/14/64	7/18/64		- 0.6
993-400-067	START STAGE 1 STATIC TEST	11/21/64	11/17/64	11/21/64		- 0.6
993-400-002	A&E CONTRACT FOR LAUNCH COMPLEX	7/08/61	7/11/61	7/08/61		0.4
993-400-006	CONTRACT FOR SECOND STAGE STATIC TEST ARTICLE	10/20/62	10/23/62	10/20/62		0.4
993-400-005	A&E CONTRACT FOR SECOND STG STATIC TEST STAND	10/20/62	10/23/62	10/20/62		0.4
993-400-041	STAGE 2 VEHICLE DESIGN INFO REQUIRED	3/09/63	3/12/63			0.4
993-400-020	START STATIC SECOND STAGE DESIGN CONTROL	3/09/63	3/12/63			0.4
993-400-046	STAGE 3 VEHICLE DESIGN INFO REQUIRED	6/22/63	6/25/63			0.4
993-400-026	START STATIC STAGE 3 DESIGN CONTROL	6/22/63	6/25/63			0.4
993-400-047	STAGE 3 MFG & ASSY FACILITY COMPLETE	10/05/63	10/08/63			0.4
993-400-061	STAGE 3 STATIC TEST STAND COMPLETE	5/23/64	5/26/64			0.4
993-400-056	STAGE 2 TEST STAND COMPLETE	8/08/64	8/11/64	8/08/64		0.4
993-400-017	BLOCK 1 STAGE 1 SOLID MOTORS DELIVERED	12/26/64	1/12/65			2.4
993-400-018	BLOCK 2 STAGE 1 SOLID MOTORS DELIVERED	7/10/65	7/27/65			2.4
993-400-039	START ASSY BLOCK 2 STAGE 1	7/24/65	8/10/65			2.4

CONFIDENTIAL

Table VII

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-400-016	STATIC STAGE 1 SOLID MOTORS DELIVERED	6/27/64	7/21/64	6/27/64		3.4
993-400-037	START ASSY STATIC TEST ARTICLE STAGE 1	7/11/64	8/04/64			3.4
993-400-052	STAGE 1 STATIC ARTICLE CHECKOUT COMPLETE	10/03/64	10/27/64			3.4

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-700-000	START APRIL 22 1961	0/00/00	0/00/00			0.0
993-700-001	PROJECT GO-AHEAD AUTHORIZED	7/01/61	7/01/61	7/01/61		0.0
993-700-099	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 27	5/06/67	5/06/67	5/06/67		0.0
993-700-009	STAGE 2 STATIC TEST ARTICLE CONTRACT AWARD	3/31/62	3/31/62	3/31/62		0.0
993-700-008	STAGE 2 STATIC TEST STAND CONTRACT AWARD	3/31/62	3/31/62	3/31/62		0.0
993-700-039	STAGE 2 STATIC TEST STAND VEH DES INFO	8/18/62	8/18/62			0.0
993-700-021	STAGE 2 STATIC TEST ARTICLE START DESIGN CONTROL	8/18/62	8/18/62			0.0
993-700-025	STAGE 2 BLOCK 3 NO 1 J-2 ACCEPTANCE STAND	11/17/62	11/17/62	11/17/62		0.0
993-700-020	STAGE MFG & ASSY FACILITY COMPLETE	12/01/62	12/01/62			0.0
993-700-011	NOT TITLED	1/05/63	1/05/63			0.0
993-700-012	NOT TITLED	1/05/63	1/05/63	1/05/63		0.0
993-700-022	STAGE 2 STATIC TEST ARTICLE J-2 ENGINES DEL	4/06/63	4/06/63	4/06/63		0.0
993-700-040	STAGE 2 STATIC TEST ARTICLE START ASSY	4/20/63	4/20/63			0.0
993-700-043	NOT TITLED	5/25/63	5/25/63			0.0
993-700-029	NOT TITLED	5/25/63	5/25/63			0.0
993-700-051	STAGE 2 STATIC TEST STAND COMPLETE	7/20/63	7/20/63			0.0
993-700-028	NOT TITLED	8/31/63	8/31/63			0.0
993-700-026	STAGE 2 BLOCK 3 NO 2 J-2 ACCEPTANCE STAND	9/14/63	9/14/63	9/14/63		0.0
993-700-052	STAGE 2 STATIC T	10/12/63	10/12/63			0.0
993-700-064	STAGE 2 STATIC TEST ARTICLE START TEST	11/23/63	11/23/63			0.0
993-700-030	NOT TITLED	1/04/64	1/04/64	1/04/64		0.0
993-700-044	NOT TITLED	1/18/64	1/18/64			0.0
993-700-055	NOT TITLED	1/18/64	1/18/64			0.0
993-700-023	STAGE 2 BLOCK 2 J-2 ENGINES DELIVERED	2/01/64	2/01/64			0.0
993-700-041	STAGE 2 BLOCK 2 START ASSY	2/15/64	2/15/64			0.0

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-700-056	NOT TITLED	4/11/64	4/11/64			0.0
993-700-024	STAGE 2 BLOCK 3 J-2 ENGINES DELIVERED	4/25/64	4/25/64			0.0
993-700-042	STAGE 2 BLOCK 3 START ASSY	5/09/64	5/09/64			0.0
993-700-031	NOT TITLED	5/23/64	5/23/64			0.0
993-700-068	NOT TITLED	5/23/64	5/23/64			0,0
993-700-045	NOT TITLED	6/06/64	6/06/64			0.0
993-700-053	STAGE 2 BLOCK 2 COMPLETE CHECKOUT	8/29/64	8/29/64			0.0
993-700-065	STAGE 2 BLOCK 2 STATIC FIRING TEST COMPL	10/24/64	10/24/64			0.0
993-700-057	NOT TITLED	11/21/64	11/21/64			0.0
993-700-054	STAGE 2 BLOCK 3 COMPLETE CHECKOUT	11/21/64	11/21/64			0.0
993-700-074	STAGE 2 BLOCK 2 RECEIVE AT LAUNCH SITE	1/16/65	1/16/65	1/16/65		0.0
993-700-069	NOT TITLED	1/16/65	1/16/65	-		0.0
993-700-066	STAGE 2 BLOCK 3 STATIC FIRING COMPLETE	1/16/65	1/16/65			0.0
993-700-078	STAGE 1 BLOCK 2 READY FOR LAUNCH SER 4	4/10/65	4/10/65	4/08/65		0.0
993-700-076	NOT TITLED	4/10/65	4/10/65	4/10/65		0.0
993-700-075	STAGE 2 BLOCK 3 RECEIVE AT LAUNCH SITE	4/10/65	4/10/65	4/10/65		0.0
993-700-101	STAGE 1 BLOCK 2 READY FOR LAUNCH SER 5	5/08/65	5/08/65	5/06/65		0.0
993-700-103	STAGE 1 BLOCK 2 READY FOR LAUNCH SER 6	6/05/65	6/05/65	6/03/65		0.0
993-700-079	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 7	7/03/65	7/03/65	7/01/65		0.0
993-700-081	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 9	8/28/65	8/28/65	8/26/65		0.0
993-700-083	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 11	10/23/65	10/23/65	10/21/65		0.0
993-700-085	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 13	12/18/65	12/18/65	12/16/65	-	0.0
993-700-087	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 15	2/12/66	2/12/66	2/11/66		0.0
993-700-089	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 17	4/09/66	4/09/66	4/08/66		0.0
993-700-091	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 19	6/04/66	6/04/66	6/03/66		0.0

Table VIII

SMS S Y S T E M

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-700-093	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 21	7/30/66	7/30/66	7/29/66		0.0
993-700-095	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 23	9/24/66	9/24/66	9/23/66		0.0
993-700-097	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 25	1/07/67	1/07/67	1/07/67		0.0
993-700-080	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 8	7/31/65	8/02/65	7/29/65		0.3
993-700-082	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 10	9/25/65	9/27/65	9/23/65		0.3
993-700-084	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 12	11/20/65	11/22/65	11/18/65		0.3
993-700-086	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 14	1/15/66	1/17/66	1/14/66		0.3
993-700-088	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 16	3/12/66	3/14/66	3/11/66		0.3
993-700-090	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 18	5/07/66	5/09/66	5/06/66		0.3
993-700-092	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 20	7/02/66	7/04/66	7/01/66		0.3
993-700-094	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 22	8/27/66	8/29/66	8/26/66		0.3
993-700-096	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 24	10/22/66	10/24/66	10/21/66		0,3
993-700-098	STAGE 1 BLOCK 3 READY FOR LAUNCH SER 26	3/04/67	3/06/67	3/06/67		0.3
993-700-005	STAGE 1 CONTRACT AWARD	9/23/61	9/30/61	9/23/61		1.0
993-700-032	LAUNCH COMPLEX VEHICLE DESIGN INFO REQUIRED	1/13/62	1/20/62			1.0
993-700-014	STATIC TEST ARTICLE INITIATE DESIGN CONTROL	1/13/62	1/20/62	1/13/62		1.0
993-700-004	A & E CONT AWD STAGE 1 STATIC TEST STAND	3/17/62	3/24/62	3/17/62		1.0
993-700-034	STATIC TEST STAND VEHICLE DESIGN INFO REQUIRED	8/04/62	8/11/62			1.0
993-700-046	STATIC TEST STAND COMPLETE	1/04/64	1/11/64	1/04/64		1.0
993-700-059	Initial first firing test	5/09/64	5/16/64	5/09/64		1.0
993-700-048	STAGE 1 BLOCK 1 COMPLETE CHECKOUT	9/26/64	10/03/64			1.0
993-700-070	LAUNCH COMPLEX COMPLETE	10/03/64	10/10/64	10/03/64		1.0
993-700-060	STAGE 1 BLOCK 1 AT LAUNCH SITE	11/07/64	11/14/64			1.0
993-700-077	STAGE 1 BLOCK 1 RDY FOR LAUNCH SER 1	1/09/65	1/16/65	1/14/65		1.0
993-700-100	STAGE 1 BLOCK 1 RDY FOR LAUNCH SER 2	2/06/65	2/13/65	2/11/65		1.0

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
993-700-102	STAGE 1 BLOCK 1 RDY FOR LAUNCH SER 3	3/06/65	3/13/65	3/11/65		1.0
993-700-006	STAGE 1 BLOCK 1 STATIC TEST ENGINES DEL	12/21/63	1/18/64	12/21/63		4.0
993-700-035	STATIC TEST ARTICLE INITIATE ASSEMBLY	1/04/64	2/01/64	1/04/64		4.0
993-700-047	STATIC TEST ARTICLE COMPLETE CHECKOUT	3/28/64	4/25/64			4.0
993-700-002	A & E CONT AWD LAUNCH COMPLEX	7/08/61	8/12/61	7/08/61		5.0
993-700-013	STAGE 1 MFG & ASSY FACILITY COMPLETE	10/13/62	12/01/62			7.0
993-700-036	STAGE 1 BLOCK 1 INITIATE ASSEMBLY	6/13/64	8/01/64			7.0
993-700-037	STAGE 1 BLOCK 2 INITIATE ASSY	9/05/64	10/24/64			7.0
993-700-049	STAGE 1 BLOCK 2 CHECKOUT	11/07/64	12/26/64			7.0
993-700-038	STAGE 1 BLOCK 3 INITIATE ASSY	11/28/64	1/16/65			7.0
993-700-061	STAGE 1 BLOCK 2 REC AT LAUNCH SITE	12/19/64	2/06/65			7.0
993-700-050	STAGE 1 BLOCK 3 COMPLETE CHECKOUT	1/30/65	3/20/65			7.0
993-700-062	NOT TITLED	3/13/65	5/01/65			7.0
993-700-007	STAGE 2 ACCEPTANCE TEST STAND CONTRACT AWARD	1/05/63	3/02/63	1/05/63		8.0
993-700-019	NOT TITLED	5/25/63	7/20/63			8.0
993-700-063	STAGE 2 ACCEPTANCE TEST STAND COMPLETE	4/25/64	6/20/64			8.0
993-700-017	STAGE 1 BLOCK 3 ENGINES DELIVERED	11/07/64	1/02/65			8.0
993-700-010	NOT TITLED	6/29/63	8/31/63			9.0
993-700-027	NOT TITLED	11/16/63	1/18/64			9.0
993-700-015	STAGE 1 BLOCK 1 FLT ENGINES DEL	5/16/64	7/18/64			9.0
993-700-067	NOT TITLED	7/11/64	9/12/64			9.0
993-700-016	STAGE 1 BLOCK 2 ENGINE DELIVERED	7/25/64	10/10/64			11.0

PART II
SECTION C

GROUND SUPPORT FOR EARLY MANNED LUNAR LANDING

S. Snyder - - - - OLVP
Col. S. L. Berry - OLVP
R. D. Briskman - - OSFP

NASA

June 16, 1961

GROUND SUPPORT
FOR
EARLY MANNED LUNAR LANDING

Introduction

This section comprises the facilities report for all ground equipment necessary to support all of the activities necessary to the total program. The facilities cover the following areas:

1. Engine, motor, and stage static test
2. Launch facilities
3. Ground instrumentation (launch and mission)
4. Life science facilities
5. Space science facilities
6. Apollo spacecraft facilities
7. Advanced technology facilities

SMS networks* were developed for all of the above facilities. However, it was not considered necessary to make computer runs for all networks since certain of these were relatively simple. Within the time available it was possible to compare the facilities needs across the various programs to eliminate duplication. In some cases it appears necessary to construct similar facilities at different sites rather than to assume that one site can be built and shared. This is felt to be a more desirable approach in the interest of limiting the amount of travel and scheduling complexity which would exist if different and complex programs were required to engage in a sharing process. This is more true, of course, for the smaller facilities such as space simulators.

Almost without exception, it became increasingly obvious as the work proceeded that facility availability is probably the major limiting factor in the earliest possible completion of total program goals. Although marginal cases exist, it appears feasible to assume a 1967 launch date subject to the following conditions as they affect facility construction:

1. Start funding no later than September 1961.
2. Assume no major catastrophy such as large explosions or continuously inclemental weather.
3. Fund construction of facilities incrementally.

4. Assume no major design failures in vehicles, spacecraft or facilities.

5. Assume that design criteria for vehicles and spacecraft will be delivered to facilities designers on a shorter than usual schedule.

6. Assume substantial relief from previous labor problems.

It was not possible to give equal attention to all problems which will require facilities support. The areas which did not receive full consideration include the recovery program, the air drop program and possible special facilities needed on the lunar surface. The first two do not appear to contain many high cost elements although more analysis is needed. Special lunar facilities will undoubtedly be required but the nature of these needs is so vague at present and the funding schedule is sufficiently well advanced so that this entire area may be treated in greater depth within the next few months without detrimental effect upon the program.

* As an index to the SMS networks and computer print-outs, the following table relates titles, SMS numbers, and the page numbers assigned to this material. A special series of pages appear at the end of this report in order to group this material in one place.

Title	SMS Network Number	Page No.	Computer Print-out Page Numbers
Launch Facilities	998100	CC 1	
Apollo Orbital	998200	CC 2	CC 11 & 12
18 Orbit Mission	998300	CC 3	CC 13 & 14
Lunar & Elliptical Missions	998400	CC 4	CC 15, 16, & 17
Miscellaneous Facilities	998500	CC 5	CC 18 - 23
C-3 Liquid Static Facilities	998600	CC 6	
NOVA Liquid Static Facilities	998700	CC 7	
R&D Engine Liquid Static Facilities	998800	CC 8	
C-3 & NOVA Solid Static Facilities	998900	CC 9	

NOTE: Page CC 10 is dropped.

LIQUID AND SOLID NOVA AND C-3 STATIC TEST AND MANUFACTURING FACILITIES REQUIREMENTS

General Assumptions (Figures 2, 3 and CC 6 THRU 9)

The test facilities requirements for a liquid NOVA and liquid C-3 are shown in Figure 2 , along with the construction times which support the Sequenced Milestone System (SMS) charts presented in the Launch Vehicle section of the report for NOVA II and C-3. The times shown would also be applicable to NOVA I and III which utilize the F-1 and the new 800-1000K H_2-O_2 motor (Y-1) in the second stage. The location of the facilities was assumed to be determined by the stage contractor selected for each of the stages. In fact, it would undoubtedly be a significant part of their proposals. The initiation and facility completion dates are indicated. In some instances, the firing dates shown are a month or two earlier than the refined SMS charts in the vehicle section. No adjustment of start date on contract award was made because no construction time contingency allowance was used.

In the process of determining the facilities schedule, the following assumptions were made:

a. Facilities are to be funded and therefore constructed on a fiscal year incremental basis.

b. Construction will be expedited to meet the facility completion dates shown.

c. Vehicle design will be expedited so that design of facilities will not be impeded by lack of vehicle configuration criteria.

d. No time consideration has been allowed for unforeseen major contingencies in areas such as delayed procurement, strikes, design changes, or delayed site selections.

e. The facilities shown are those required in addition to facilities already being used in the Saturn, F-1 and J-2 development programs.

f. Facilities will not all be initiated at once but rather will be initiated as required to meet the schedule with a reasonably paced construction effort.

Liquid Nova

For each stage the static test facilities consist of two test positions and one blockhouse. One of the positions is to be utilized for R&D. The other would be both an acceptance stand and a back-up R&D stand. In the latter role, the second position for each stage should be available

about the time of the first firing of the static test stage.

Both first and second stage test facilities are new. The third stage test facilities are modifications of static test facilities existing from the ICBM program. Manufacturing facility modifications of a fairly extensive nature are required for the fabrication of both first and second stages. The times required for such modifications are consistent with the stage development times presented in the launch vehicle section of the report.

Liquid Saturn C-3

Three 1st stage positions are planned. Because of the heavy firing schedule for C-3 (one a month) a back-up acceptance stand is included. The availability of this stand could permit an increase over the one a month rate since the launch complex is designed for more than one a month.

The second stage static test facilities included two positions. The third position, as a backup, was not planned since the possibility exists that one of the stands for the third stage of NOVA could be modified for the thrust of two additional J-2's and could therefore be a stand-by for both stages.

The third stage static stand of one position is in addition to the existing stands being used for S-IV that would be available.

Manufacturing facility modifications for both 1st and 2nd stages are required and their scheduling is consistent with the stage development times.

Liquid Engine Test Stands

The production rate of both F-1 and J-2s require four acceptance stands for each. The completion of them can be staggered as indicated in Figure . If the Y-1 (large H_2-O_2 engine) were selected for the NOVA second stage, one less J-2 acceptance stand would be required.

The Y-1 R&D engine facilities are initiated as soon as the Y-1 contract, and are available about a year later. If this engine were selected for the second stage of NOVA, two additional acceptance stands would be required.

Solid NOVA and Saturn C-3 Test Facilities Requirements

The facilities shown in Figure CC9 are for the first two solid stages of NOVA and the first solid stage of C-3. The other stage facilities are the same as those required for the all liquid vehicles. The second and third stages of the all-liquid NOVA become the 3rd and 4th stages of the solid-liquid NOVA.

The starting dates indicated are for a reasonably paced construction program. These facilities could, of course, be started earlier to provide

further assurance of meeting the schedule or to permit earlier cluster firings if motors were available.

Manufacturing facilities for all solid stages will be required and their scheduling is consistent with the stage development schedules.

Description of Solid Static Test Complex

A static test complex for firing solid propellant stages will be constructed on a government-owned reservation. The complex will have at least three test pads capable of withstanding thrust of approximately 25M lbs., with a central control room common to all pads. This facility will be used for testing the first stage and second stage of the NOVA and the C3 stage. In addition to the three high thrust pads, it is expected that at least one small test stand capable of absorbing thrust of approximately $3\frac{1}{2}$M lbs. will be built.

The schedules are based on estimates from propulsion contractors, metal part vendors and engineering companies familiar with solid motor facility construction.

In extrapolating to the high thrust levels characteristic of NOVA stages it must be kept in mind that the control center does not change as the thrust level of the motor or stages increases. The basic change therefore is in the extension of roads, utilities and electricity as distances are increased for safety reasons, and in the pouring of larger concrete pads and footings to take the higher thrust. The method of testing to be used for these solid stages will be with the exhaust directed upward and the thrust taken downward into the concrete pad. This calls for relatively simple and inexpensive construction. In addition to the pad, it is expected that vertical supports, which may consist of steel girders or adjacent concrete walls, will be used both to support the motor and to provide for measurement of side forces.

Solid Stage Development Facilities

The stage development contractor will require facilities and buildings to perform stage structure assembly and evaluation, (but not for full static test of the stages). It is assumed that two contractors will be involved, one for the NOVA first stage and one for the C3 and NOVA second stage, therefore the facilities may have to be duplicated.

The items listed above are the total of new facilities required of the NASA for the development of the solid propellant stages. Each contractor will need certain special handling equipment and tooling, but this category of purchase is normally called Special Tooling and is provided under the development funds rather than facilities funds.

Actions Required

Figure 1 , presents the contract actions required to undertake the parallel development of both liquid and solid-liquid NOVA and C-3.

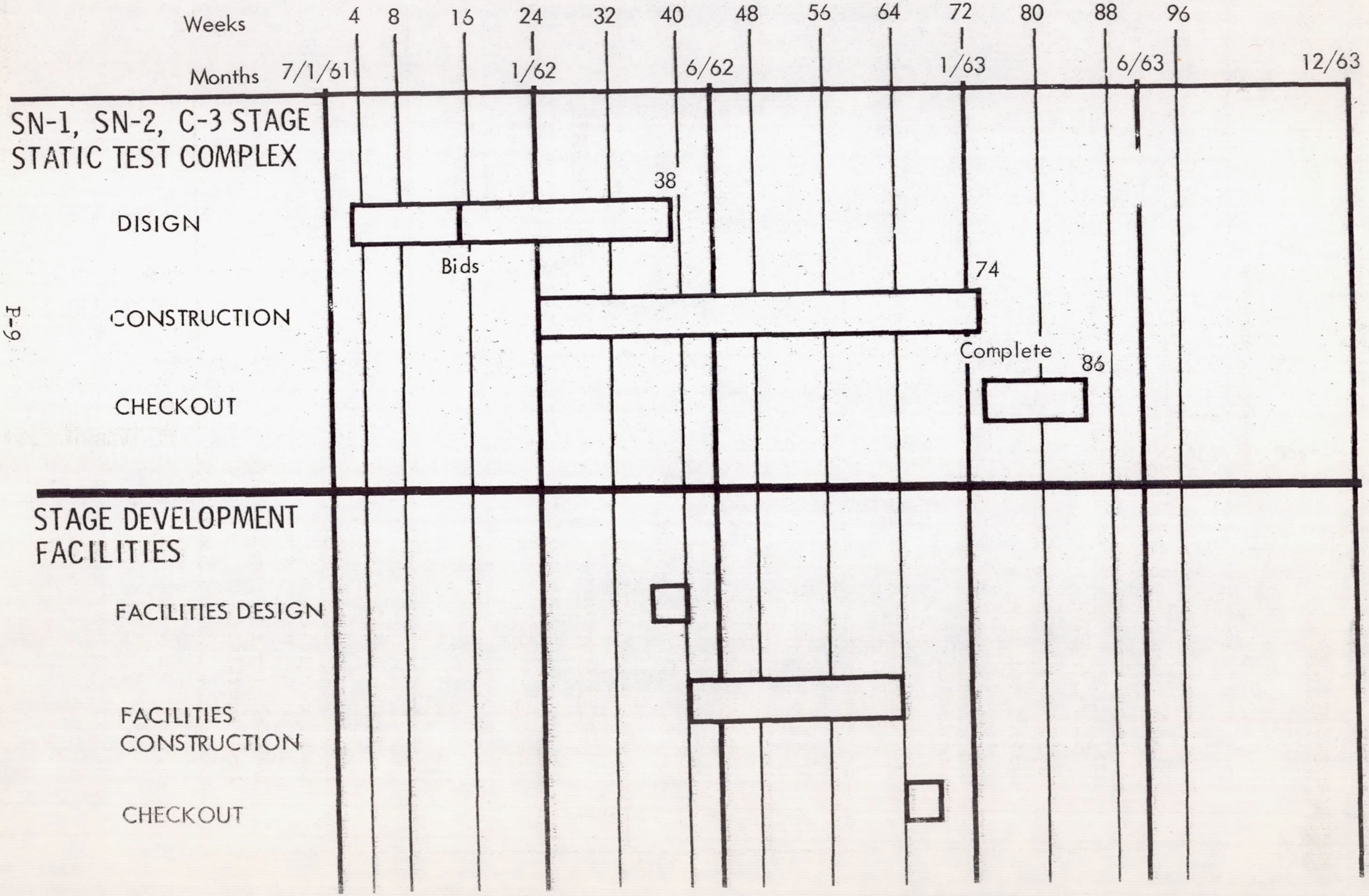
CONTRACT ACTIONS REQUIRED

FY 62	FY 63
First Quarter 1. First stage liquid NOVA static test facilities 2. First stage liquid C-3 static test facilities 3. F-1 acceptance stands 4. J-2 acceptance stands 5. Y-1 test facilities	**First Quarter** NONE
Second Quarter 1. None	**Second Quarter** 1. Second stage solid static test facilities
Third Quarter 1. Second stage liquid NOVA static test facilities	**Third Quarter** 1. Third stage liquid NOVA static test facilities 2. Third stage C-3 static test facilities
Fourth Quarter 1. First stage solid NOVA static test facilities 2. C-3 solid first stage static test facilities	**Fourth Quarter** NONE

FIGURE 1

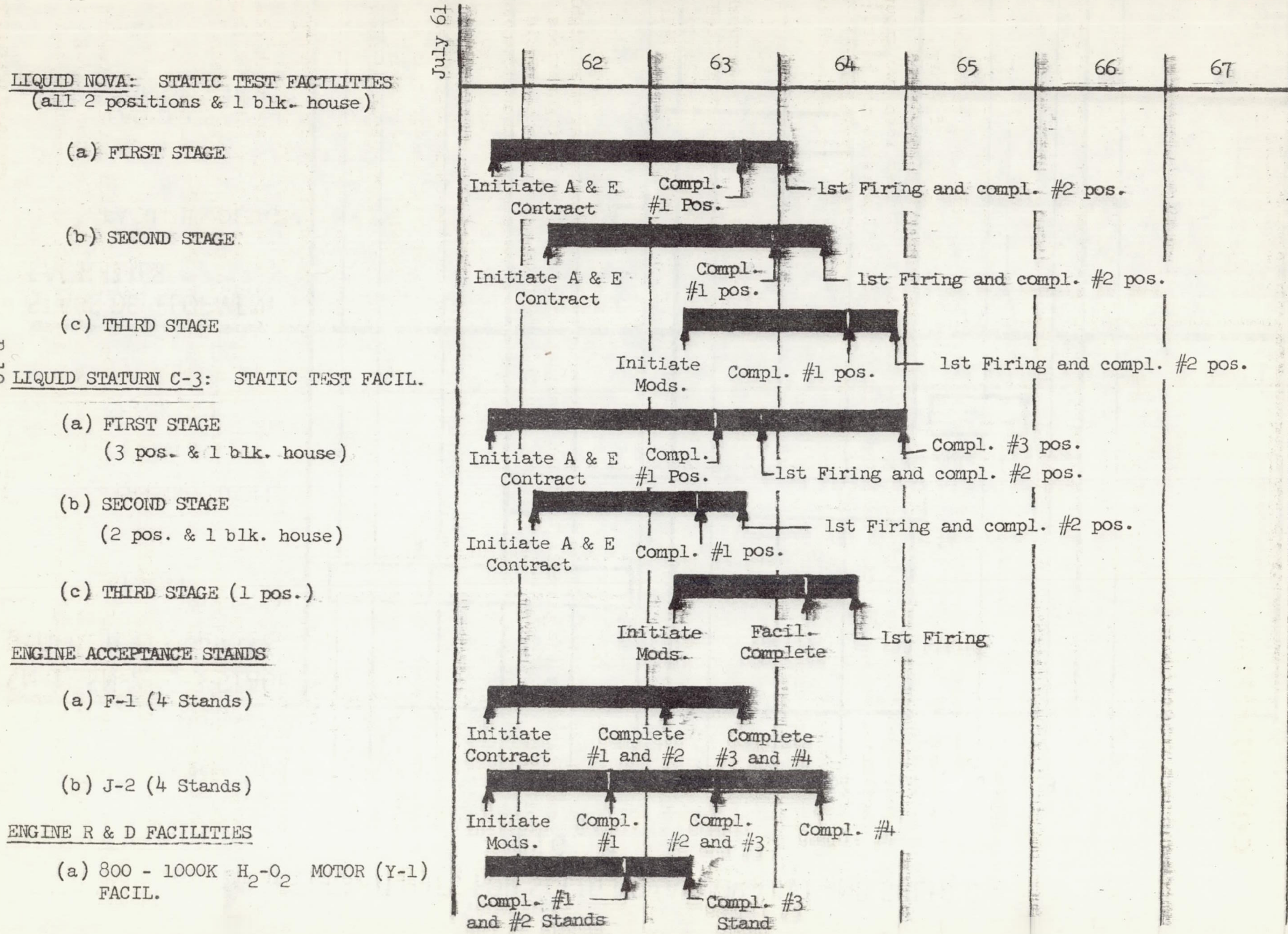
TEST FACILITIES FOR SOLID NOVA (NOVA IV) AND SOLID C-3

FIG. 3



LIQUID NOVA II & LIQUID C-3 TEST FACILITY REQUIREMENTS SCHEDULE

FIG. 2



Ground Support
For
Early Manned Lunar Landing

Launch Facilities

Introduction

This section considers all major aspects of facilities and resources necessary to launch C-3 and NOVA and the increased quantities of Delta, Atlas Agena, and Centaur vehicles required to support the unmanned and manned phases of the lunar program. The material is divided into two groups, facilities and schedules. Based upon the vehicle configuration now postulated, certain preferred solutions to the launch facilities question will be discussed. Additional background on other solutions is also included as a matter of record to indicate the scope of the analysis.

Scheduling of facilities construction is treated by describing the SMS network which was constructed to cover C-3 and NOVA, only. No networks were developed for Delta-Agena-Centaur facilities since these possible construction programs are felt to be relatively straight forward. Similarly, a lack of information on the specifics of the recovery program has prevented detailed analysis of facilities needs.

Not as a matter of apology, but as a statement of fact, it must be recognized that the approach to the total facilities problem has been highly complicated by the permutations and combinations of vehicle configurations which had to be taken into account. In this respect, the issue of liquid vs. solid boost was the greatest single factor. Since preservation of schedules was maintained as the single major objective, it was concluded that few facilities could be shared between liquid and solids and that design and construction of separate facilities must proceed until a choice can be made between the two. This is admittedly expensive. Some hope exists that a retrofit might be possible after one or the other booster is selected. But the dual approach is critically important to the 1967 launch date and does not appear susceptible to compromise.

Finally, it should be understood that the program life budget which evolved from the facilities layout is no better than the short amount of time which could be devoted to the subject. At this writing, and with the continued assumption of the dual liquid-solid approach, it is possible that the budget may be inadequate by approximately \$200-\$400M. The reason for this new input will be discussed in the Facilities portion.

Vehicle Assembly and Launch Concepts

In the early portion of the study a strong inclination existed toward assuming that liquid C-3 and NOVA could be assembled and launched using very nearly identical approaches. Solid C-3 and NOVA also seemed capable

of being handled by like techniques between one another. For the case of the liquids, the preferred system hinged upon use of the "new MSFC approach." This approach involves a large separation (over 1 mile) between launch pad and launch control. Thus, a costly blockhouse is eliminated. In its place, an assembly/control building is used. A number of assembly and checkout bays make up this building. The equipment which is used to checkout the vehicle is also used for launch, eliminating much expense. A key element involves vertical assembly, in which the umbilical remains attached to the vehicle until launch. Because of this feature, mating integrity is preserved, and laborious re-checks now experienced because of incessant mating and separation are avoided. As a result of the geographic separation between control and launch pads, a technique of long distance digital data transmission must be employed to eliminate line loss and interference associated with analog transmission. Another advantage of the new approach results from the elimination of costly gantries, since the function of gantries, namely stage mating, is accomplished in the assembly building.

As the study progressed, two facts emerged which altered, drastically, the liquid solutions. First, the case for use of the "new approach" requires high launch rates. For instance, three pads based upon conventional techniques cannot yield a rate much greater than about 15 launchings per year. The "new approach" using three pads will result in a capability of 48-50 per year. Initial investment costs for the new approach are, however, higher than for conventional techniques. In comparing C-3 and NOVA launch rates, it was apparent that C-3 could eventually benefit from the new approach, whereas NOVA does not indicate a sufficient number of yearly launches, certainly through 1968-1969. The second fact was that there is a practical limit to the size of a vehicle which can be transported a mile or more in a vertical position. This limit now appears to be exceeded by NOVA, which may be 350 feet, or more, in height. C-3 layouts place it in the 250-300 foot category, acceptable for vertical transportation.

For solids, it appears extremely unlikely that vehicles will be fully assembled at any place other than at the launch pad. Here, weight is the limiting factor. As an example, the existing Saturn Complex 34 movable gantry weighs about 5,400,000 pounds. Great pains were necessary to design synchronized drive, rails and supporting members for this structure which moves only 600 feet. A solid C-3 will weigh on the order of 6 million pounds not including the transporter and "A" frame supporter, which would raise this figure to at least 8,500,000 pounds. Optimistically, the solid NOVA vehicle would weigh in the 20 million pound region. Moreover, the transport distances for either the C-3 or NOVA would be at least 80 times greater than for the Complex 34 gantry. Assembling portions of these vehicles for delivery in the vertical position does not appear attractive since no advantage can be taken of the continuous mating between the

umbilical mast and vehicle. Because of this, a prime feature of the new MSFC approach, high launch rates, would be lost.

In summary, based upon presently understood configurations, only liquid C-3 lends itself to use of the vertical assembly-transport concept. Solid C-3 and liquid and solid NOVA must be assembled at the pad. Launch site layouts for all four vehicles will be reviewed after a discussion of range and pad siting, which follows.

Range and Pad Siting

This subject area undoubtedly received the greatest amount of attention of any major question in the study. It is apparent that range and pad siting influence costs and schedules heavily. At the onset of the study it appeared necessary to resolve four issues in order to determine where the launch ranges should be located and how the sites should be constructed at the ranges. These issues were:

1. Mission needs (i.e. Easterly vs Polar launch)
2. Sound level
3. Launch rates
4. Explosives and other hazards

Even with the meager amount of vehicle data available, initially, it appeared very unlikely that polar launches of C-3 or NOVA would be necessary, thus eliminating the Pacific Missile Range (PMR) from consideration in this area. The remaining three questions did suggest, by their very nature, that serious problems might exist at the Atlantic Missile Range (AMR).

The matter of sound levels is far and above the most serious controversial issue. A predominant reason for this situation is that little data exists in the measurement of sound levels above 1.5 million pounds of thrust. Early in 1961 MSFC awarded several study contracts concerning the development, construction and launch of vehicles in the 6-12 million pound class. Data from the first reports of two of the companies, Lockheed and North American, was available. These reports included calculations of large vehicle sound levels. Typically, Figure 1 shows that sound approaching the threshold of pain would exist 5-10 miles away from the site of a 12 million pound stage. At the time it was felt that sound levels of such a magnitude might be unacceptable at AMR and studies were started to investigate other sites. Parallel to this effort, an assignment was given to the Chairman of the Advanced Technology Group to collate data available at Langley, Lewis, and Ames so that a more practical relationship could be established between theoretical calculations and actual experience. The results of this work are contained in the report of the Advance Technology Group.

NOISE LEVELS VERSUS DISTANCE

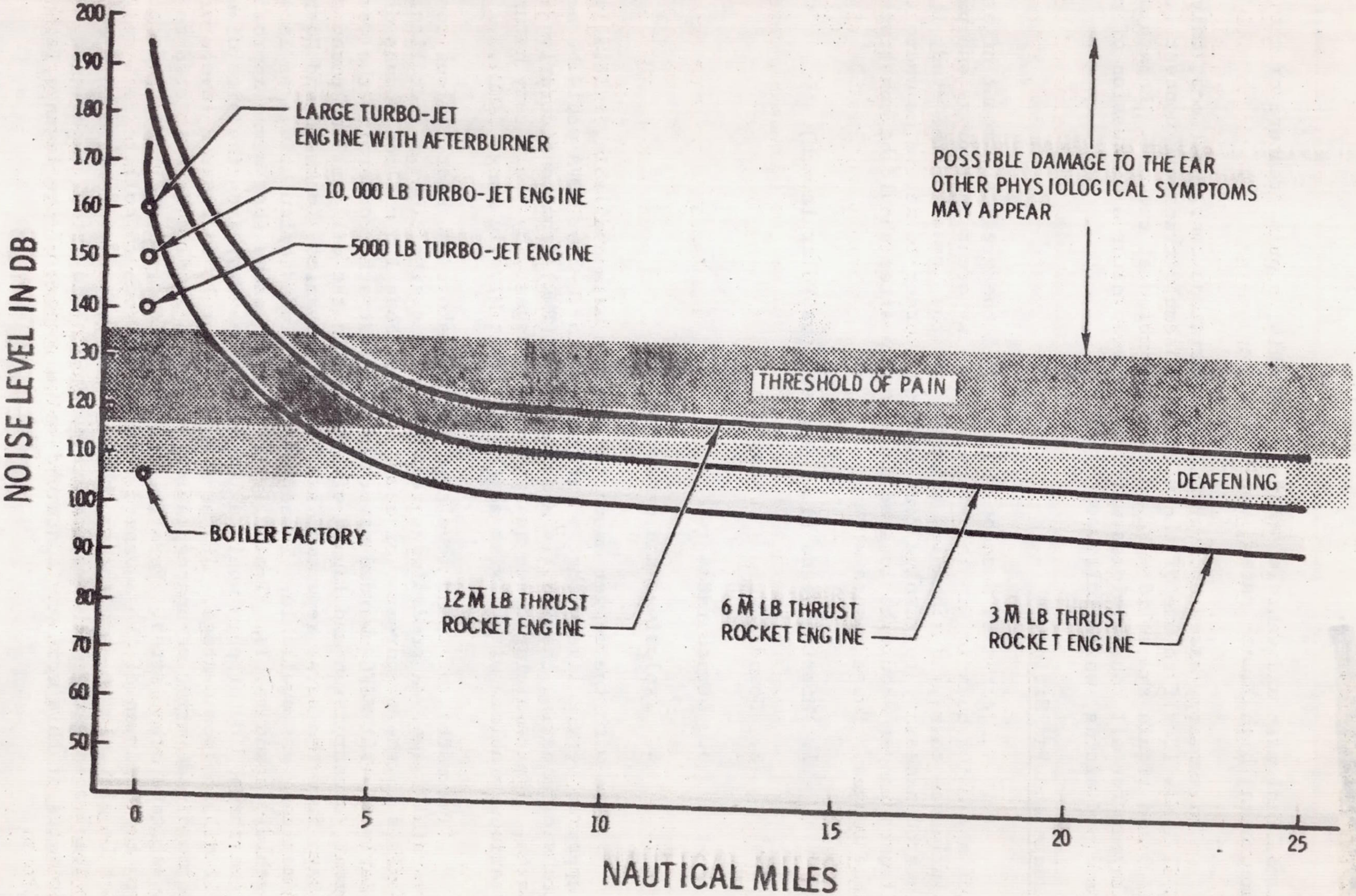


FIGURE 1

As a second parallel effort, Headquarters, Launch Operations reviewed the general sound problems with the Launch Operations Directorate (LOD), MSFC. From this, LOD created an ad hoc working group with participation by AMR and Edwards Air Force Base. The first summary report of this group is attached as Appendix CI. It is an outstanding summary, particularly recognizing the fact that it was accomplished within a two-week period. The salient features of the report are that:

a. It is preferable to discuss sound problems in terms of sound pressure levels which will be experienced at certain frequencies, rather than simply in terms of acoustic noise.

b. Within the region where levels of 120 db will be experienced, acoustic protection (sic. control) will be necessary for humans.

c. Within the larger radius where 115 db will be experienced, the geographic boundaries should be owned by the Government to preclude civil damage suits.

d. Damage to structures may occur at various distances, depending upon the nature of the construction, weather, and other factors.

e. An aggressive sound measurement and analysis program must be undertaken immediately at AMR and other locations. (NOTE: It was recognized that a measurement effort has been in progress for some time at MSFC during Saturn static tests. Results of this data indicate a strong inter-dependence between weather, principally temperature inversion, and sound transmission.)

f. For a 12 million pound stage, sound pressure levels of 115 db will be experienced at 11 miles; 120 db will be experienced at 6 miles. At 20 million pounds, and assuming similar sound levels, the distances increase to 15 and 8 miles, respectively.

The obvious value of this report is that it has served as a more practical "anchor point" in deciding where launch sites might be located at AMR. It is based upon the considered opinions of a number of experts covering the vehicle, structural, safety, biomedical, and land acquisition fields. The methods by which the findings of the group were applied to the specific needs of C-3 and NOVA will be considered after a review of the activities which led to the choice of AMR as the preferred East Coast site.

It should also be recognized that the material in the report cannot be considered as conclusive, but more as a recapitulation of data which had previously existed. For example, Figure 2 which was constructed as part of the study indicates an improvement in the sound problem from the situation which appears in Figure 1. More data available after the completion of the ad hoc report indicates that further optimism may be possible, as relating to the extent that persons may operate within a 120 db region without control of their movements.

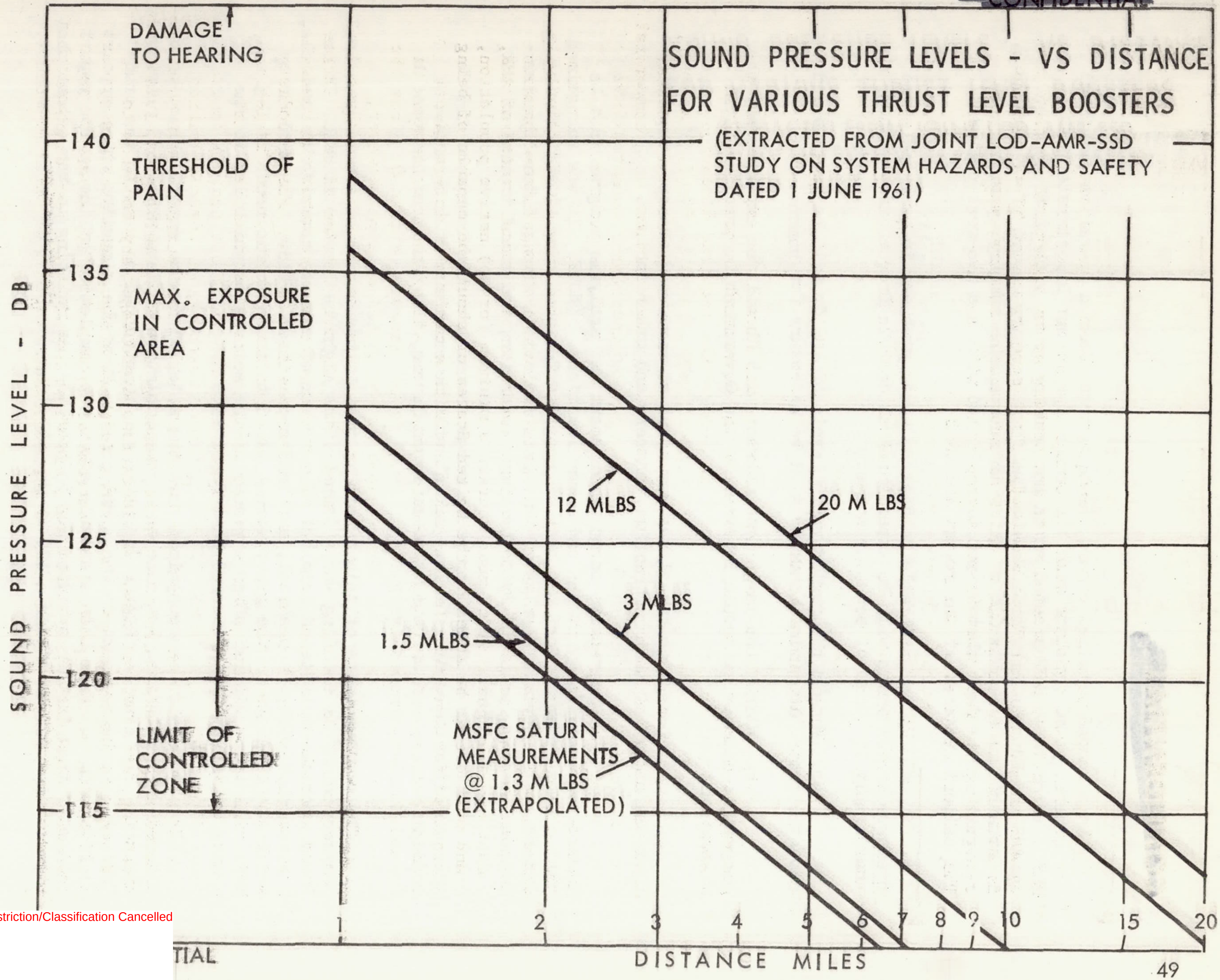

SOUND PRESSURE LEVELS - VS DISTANCE
FOR VARIOUS THRUST LEVEL BOOSTERS
(EXTRACTED FROM JOINT LOD-AMR-SSD
STUDY ON SYSTEM HAZARDS AND SAFETY
DATED 1 JUNE 1961)
DAMAGE TO HEARING
THRESHOLD OF PAIN
MAX. EXPOSURE IN CONTROLLED AREA
LIMIT OF CONTROLLED ZONE
140
135
130
125
120
115
SOUND PRESSURE LEVEL - DB
20 M LBS
12 MLBS
3 MLBS
1.5 MLBS
MSFC SATURN
MEASUREMENTS
@ 1.3 M LBS
(EXTRAPOLATED)
1
2
3
4
5
6
7
8
9
10
15
20
DISTANCE MILES

FIGURE 2

Choice of AMR

During the period that study groups were being created to evaluate the sound level and associated problems, it appeared desirable to explore the range of choices which might exist at places other than on-shore at AMR. The most interesting candidates were:

1. Southeast Florida (below Miami)

2. The down range island chains

3. Southeast Georgia coast

4. Off-shore at AMR

Analysis of the southeast Florida region, Figure 3 , showed that a site adjacent to the Atlantic Ocean would be required, if overflight of populated areas is to be avoided. No area of the required dimension, at least 10 mile radius for even the liquid NOVA, could be found. Moreover, should such a site have been located it would require blocking off coastal highways during operations and would result in serious impact upon commercial and sport fishing in the area. This siting was therefor eliminated from further consideration.

A study of the possible down range island chains showed that relatively few actual choices exist since the island may not be too far from the mainland, must be situated within the instrumentation positional limits of AMR, must be of adequate size, must contain a minimum (or no) native population, and must either be owned by the United States or should be capable of being acquired for long term lease quickly and with a minimum of international complications. No island was located which met all of these criteria. Of a number considered, Great Abaco Island in the Bahamas, Figure 4 , has the most attractive features. It is owned by the United Kingdom, however, and is populated. Aside from the question of meeting the above criteria, which are demanding in themselves, is the question of cost. Price comparisons between mainland and island installations show that the remote sites cost at least twice mainland sites even in areas contiguous to the United States, and not including the more expensive maintenance charges. To create an island installation requires, literally, a duplication of most mainland support resources. Typically, these include central control building, docks, air strip, shops, offices, warehousing, instrumentation, steam generation plant (at least 10,000 KVA plus distribution), water supply, water wells, range safety, barracks, messing, security, mainland-to-island cabling, etc. All of these considerations discouraged any tendency to delve into the matter of island sites further, although the possibility was held in reserve pending the outcome of noise and safety studies. The studies which were completed later, and which have already been discussed, show that remote island siting is not required.

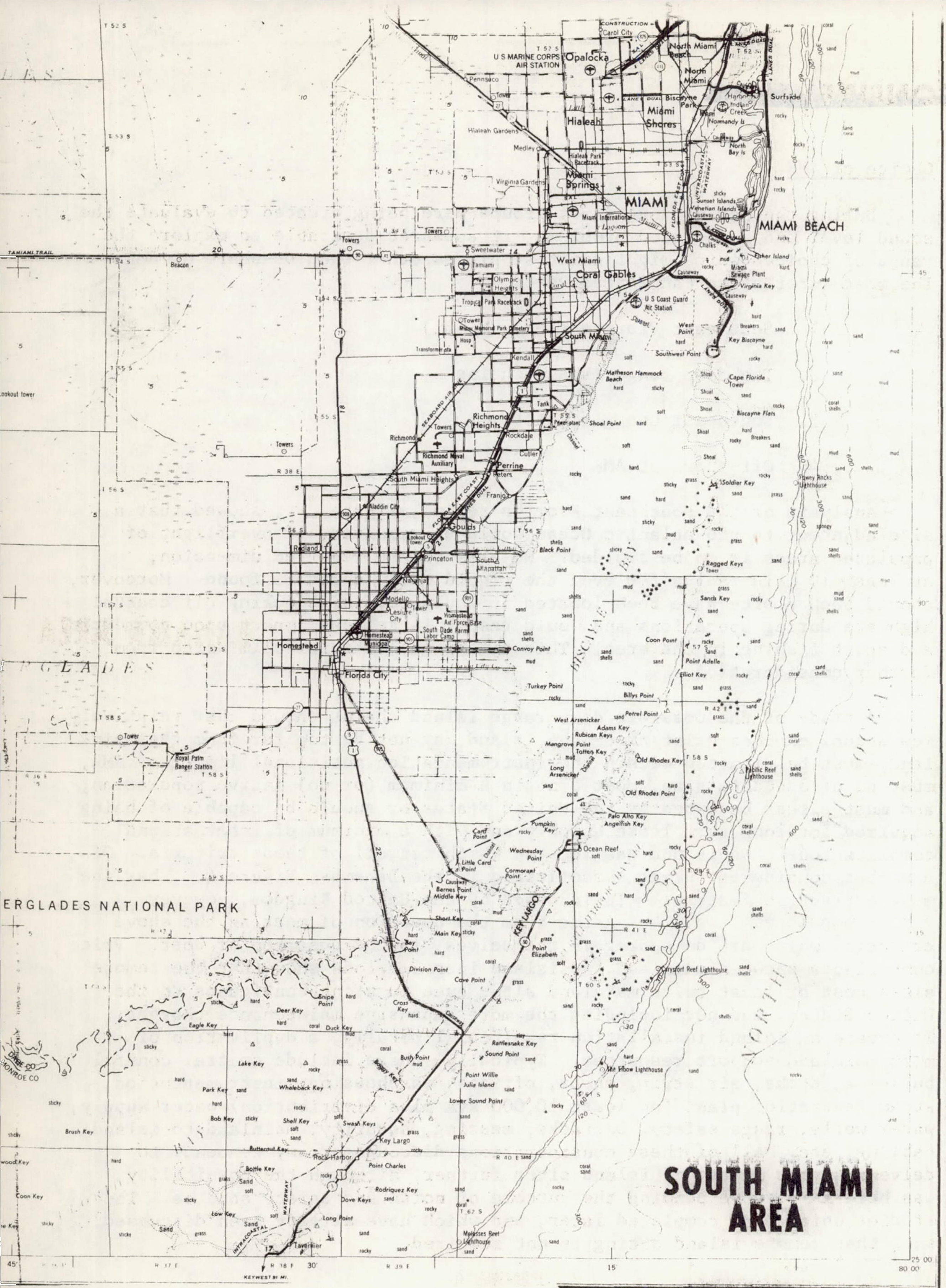

SOUTH MIAMI AREA
MIAMI
MIAMI BEACH
Opalocka
U S MARINE CORPS AIR STATION
North Miami Beach
North Miami
Biscayne Park
Surfside
Miami Shores
Hialeah
Hialeah Gardens
Medley
Miami Springs
Virginia Gardens
Miami International
West Miami
Coral Gables
Sweetwater
U S Coast Guard Air Station
Key Biscayne
Cape Florida
South Miami
Kendall
Richmond Heights
Rockdale
Perrine
Cutler
Richmond Naval Auxiliary
South Miami Heights
Goulds
Princeton
Redland
Naranja
Modello
Leisure City
Homestead Air Force Base
South Dade Farm Labor Camp
Homestead
Florida City
Convoy Point
Turkey Point
Soldier Key
Ragged Keys
Sands Key
Elliot Key
Adams Key
Rubicon Keys
Totten Key
Old Rhodes Key
Old Rhodes Point
Palo Alto Key
Angelfish Key
Ocean Reef
Pacific Reef Lighthouse
Fowey Rocks Lighthouse
Carysfort Reef Lighthouse
The Elbow Lighthouse
Molasses Reef Lighthouse
KEY LARGO
Key Largo
Rock Harbor
Tavernier
Royal Palm Ranger Station
TAMIAMI TRAIL
ERGLADES NATIONAL PARK
ERGLADES
Lookout tower
Towers
Beacon
INTRACOASTAL WATERWAY
KEYWEST 91 MI.
DADE CO
MONROE CO
INTERIOR GEOLOGICAL SURVEY, WASHINGTON D.C. 1958 NS
M R 3674

FIGURE 3

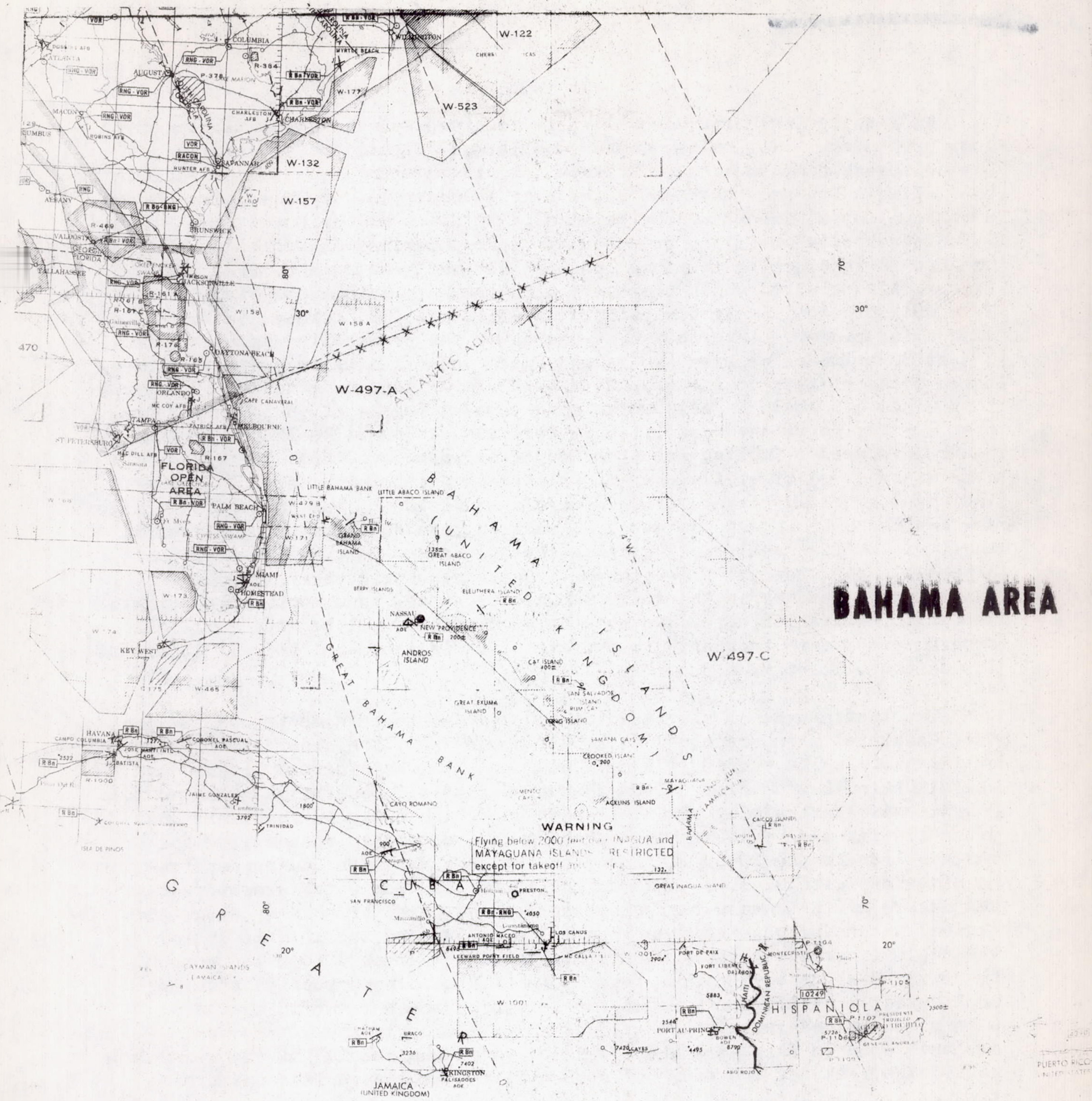

BAHAMA AREA
W-122
W-523
W-177
W-132
W-157
W-158 A
W-497-A
W-497-C
W-479 B
W-171
W-173
W-465
W-1001
ATLANTIC ADIZ
COLUMBIA
AUGUSTA
MACON
CHARLESTON
SAVANNAH
HUNTER AFB
BRUNSWICK
VALDOSTA
TALLAHASSEE
JACKSONVILLE
DAYTONA BEACH
ORLANDO
CAPE CANAVERAL
TAMPA
MELBOURNE
ST PETERSBURG
MAC DILL AFB
FLORIDA OPEN AREA
PALM BEACH
MIAMI
HOMESTEAD
KEY WEST
LITTLE BAHAMA BANK
LITTLE ABACO ISLAND
GRAND BAHAMA ISLAND
GREAT ABACO ISLAND
BERRY ISLANDS
ELEUTHERA ISLAND
NASSAU
NEW PROVIDENCE
ANDROS ISLAND
CAT ISLAND
GREAT EXUMA ISLAND
LONG ISLAND
CROOKED ISLAND
ACKLINS ISLAND
CAYO ROMANO
BAHAMA ISLANDS (UNITED KINGDOM)
GREAT BAHAMA BANK
HAVANA
CUBA
PRESTON
LEEWARD POINT FIELD
WARNING
Flying below 2000 feet over INAGUA and MAYAGUANA ISLANDS RESTRICTED except for takeoff and landing
GREAT INAGUA ISLAND
HAITI
DOMINICAN REPUBLIC
HISPANIOLA
PORT AU PRINCE
JAMAICA (UNITED KINGDOM)
KINGSTON
GREATER
PUERTO RICO

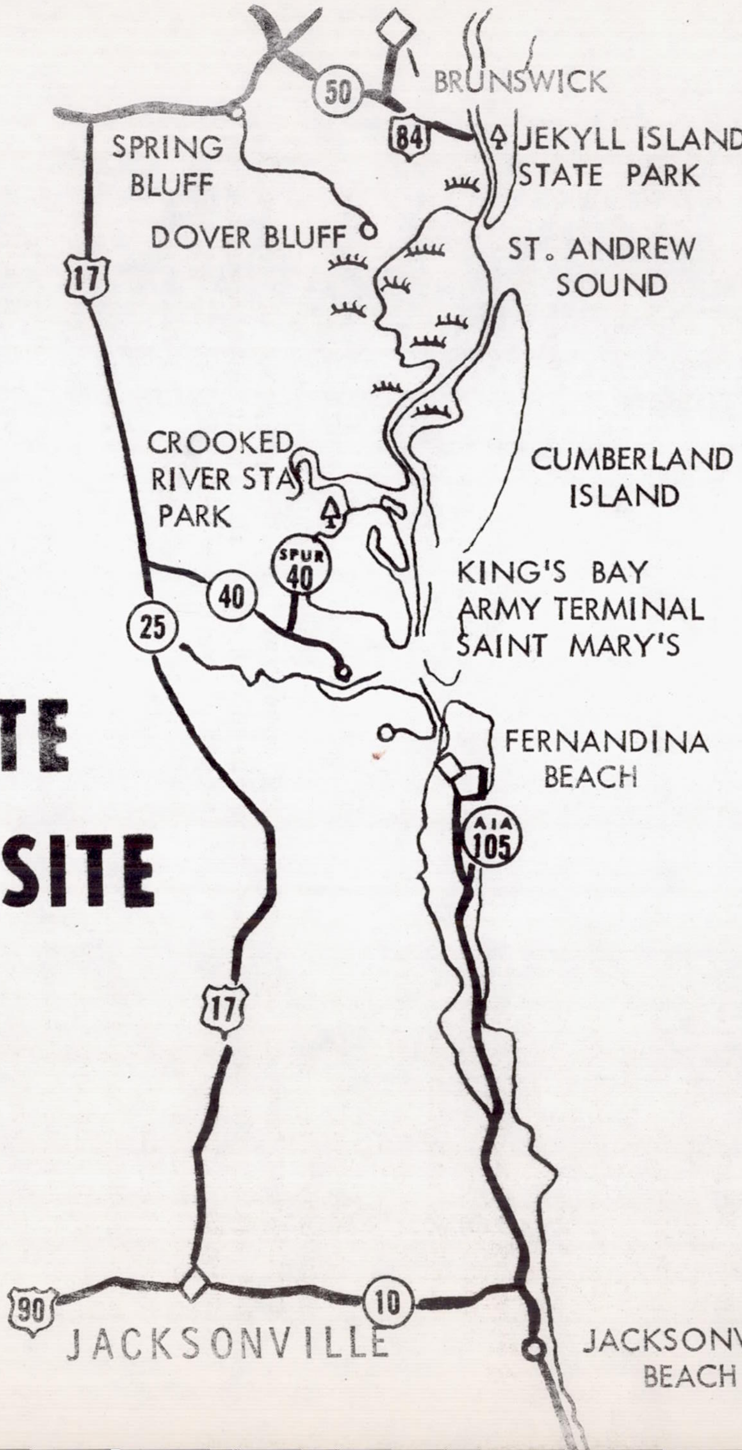
FIGURE 4

An interesting third possible site received some attention during the four week study. This site, Cumberland Island, Figure 5 , is located off the southeast Georgia coast. As shown, it is adjacent to a reserve military base, King's Bay Army Terminal. The base is controlled by Hqs., Army Transportation Corps, Brooklyn Army Terminal. Possible use of Cumberland Island as a launch site was first proposed by representatives of Lockheed, Georgia who had no interest in this use, per se, but who took note of its capabilities. This occurred while they were negotiating possible use of the Terminal for static test of the Saturn S-II stage, if Lockheed is the successful bidder. A cursory analysis shows the possibility of installing two or more launch pads on the island, with sound limits extending to populated areas similar to the case at AMR. Initial data on meteorology suggests that winds are about 5 knots worse than at AMR; fog is slightly worse; the past 10-year hurricane history shows that the Jacksonville-Brunswick area has been spared. Housing and other major support facilities are virtually non-existent. A brief fly-over of the island and terminal area on 5 June indicated generally favorable topographic conditions. The Commanding Officer, AMR and the LOD have appointed an inspection team to assess site potential in detail. First analysis indicates that the area might be considered as a possible site for solid launchings. However, considerable problems exist such as trends in the solid vehicle programs, land acquisition, instrumentation, logistics, etc. No conclusive findings will be made until the program progresses further. In any event, it is probable that all liquid launchings will be made from AMR.

The fourth area of site studies involved the waters contiguous to the Cape Canaveral area, referred to as off-shore AMR. The need for off-shore siting has been an extremely fluid question. In the progress of the work, the situation has developed from the point that all launchings appeared to require off-shore siting to the present condition where up to 12 million pound liquids may be launched on-shore and an uncertain case exists for large solids in the 20-30 million pound solid class. On the assumption that an off-shore site might be needed, the first question which arose dealt with the nature of the underwater conditions at the Cape. Figure 6 shows some typical water depths extending 10 miles out. Beyond the 10 mile region the depth increases greatly, and it is considered that a 10 mile radius is the maximum since beyond this range very difficult construction problems would exist. An attempt was made to determine whether sufficient data exists on the underwater geology. It appears that little if any work has been done in this area and for this reason one portion of the scheduling activities includes the start of core drilling at the earliest possible time.

~~CONFIDENTIAL~~

POSSIBLE ALTERNATE LAUNCH SITE



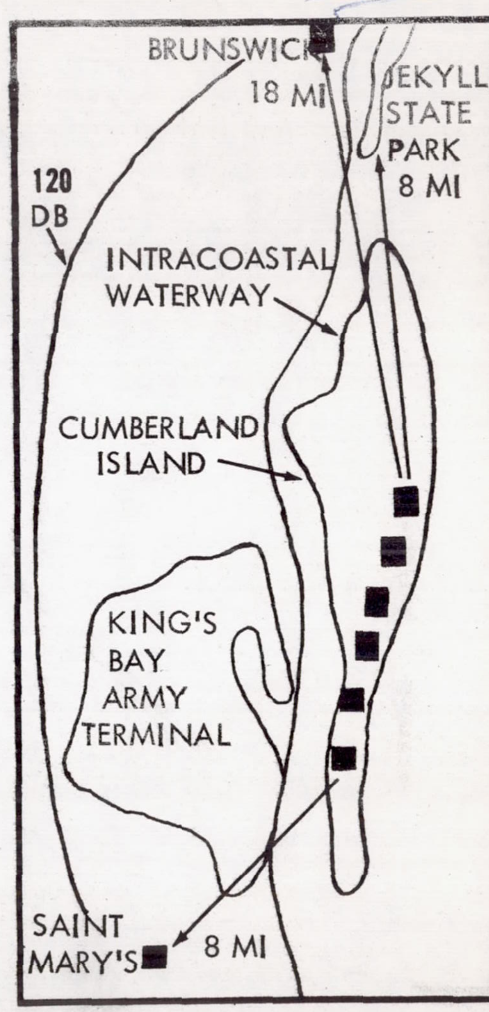


FIGURE 5

-21-

[redacted]

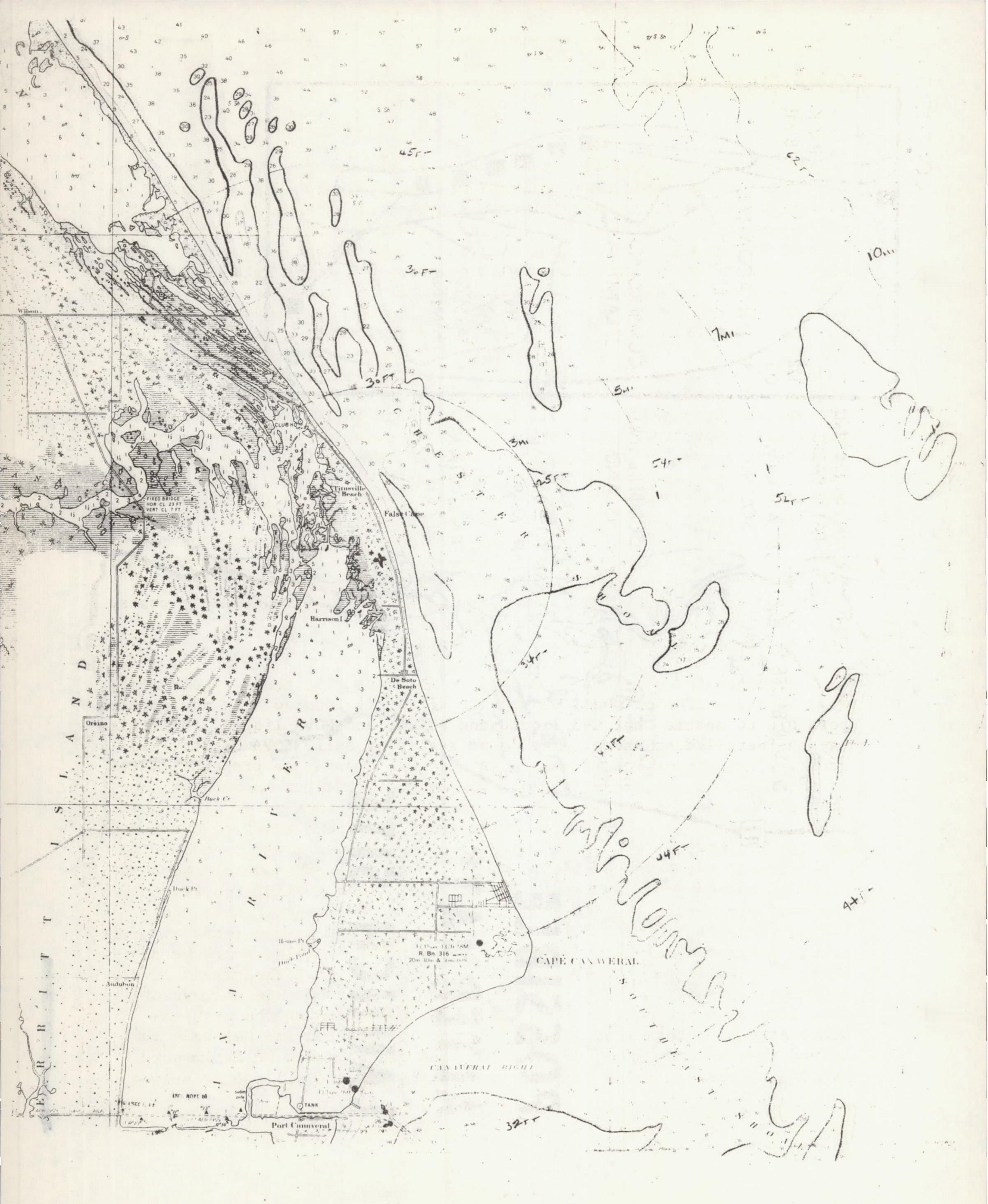
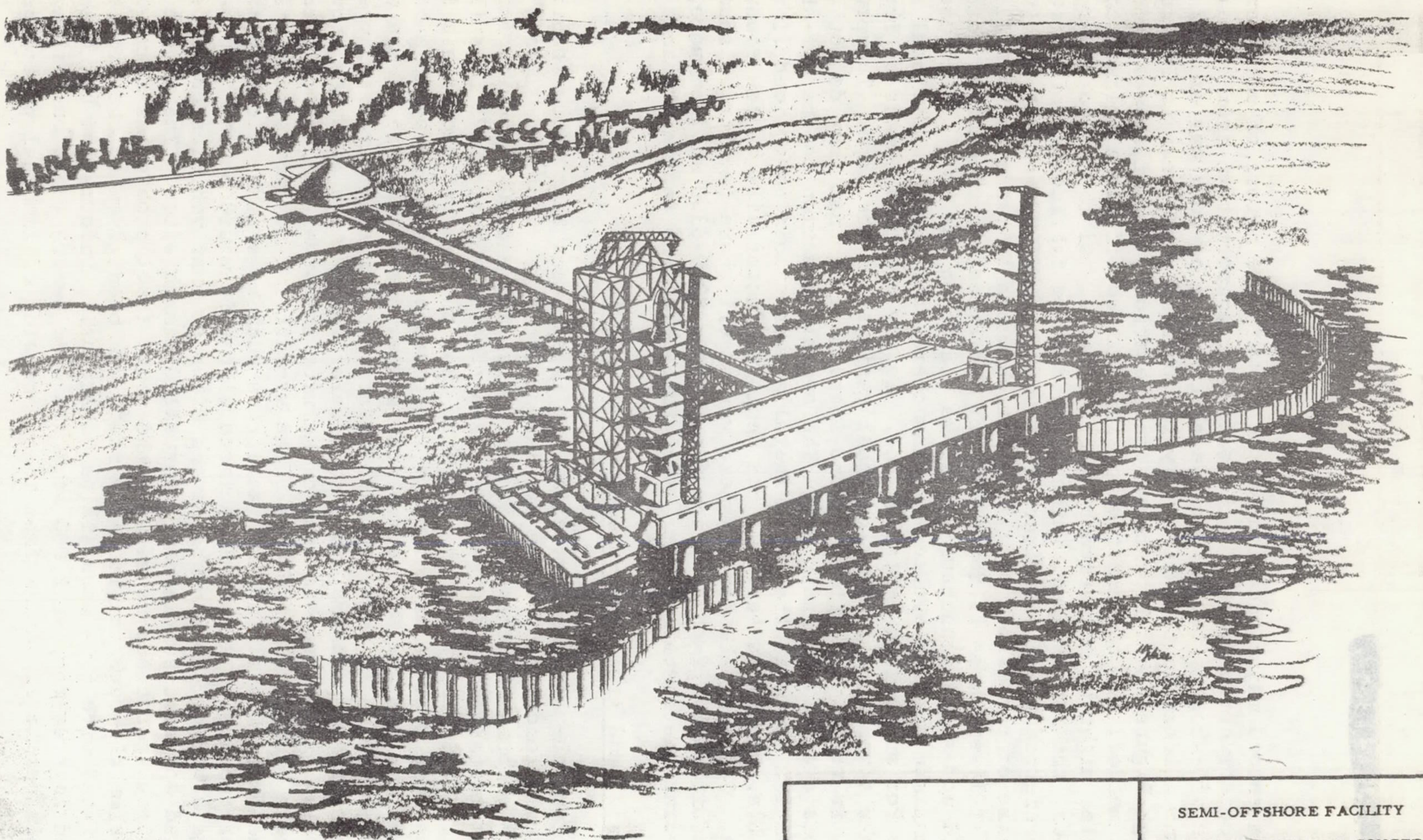

Titusville Beach
False Cape
Harrison I
De Soto Beach
CAPE CANAVERAL
CANAVERAL BIGHT
Port Canaveral
Audubon
Wilson
Orsino
Buck Cr
CLUB HO
TANK
FIXED BRIDGE HOR CL 23 FT VERT CL 7 FT
R. Bn. 316
45 FT
30 FT
25 FT
54 FT
52 FT
34 FT
32 FT
3 MI
5 MI
7 MI
10 MI

FIGURE 6

A second major question had to do with the nature of off-shore facilities construction and the techniques of transportation from the mainland to the off-shore site. A considerable amount of work was done to collect all known ideas in this area. Typical methods are shown in Figure 7 through Figure 15. From these considerations, selection was made of one basic method, the construction of land filled off-shore islands to which vehicles might be delivered by rail or barge. Of these two transportation methods, the rail system, which would require fabrication of trestles, is the preferred technique since it is less dependent upon sea conditions. The size of the island or islands which would be constructed will depend upon at least three factors: First, determination of whether both the liquid and solid launchers should be placed on the same island; second, the maximum spacing between all launchers, and third, additional space needs for supporting installations. In any event, it would be important to take advantage of existing shoal regions off the Cape. The problem here, is to so place these island installations that they do not create serious overflight conditions. The overall reaction to the off-shore facilities issue is that such installations should be avoided if at all possible. As noted earlier, the deciding factor will be the sound level issue. Costing data for on-shore versus off-shore facilities shows that the additional off-shore price for NOVA is $200-$300 million more, not including the sustained commitment for operations and maintenance costs.

Cape and Land Area Requirements C-3 and NOVA

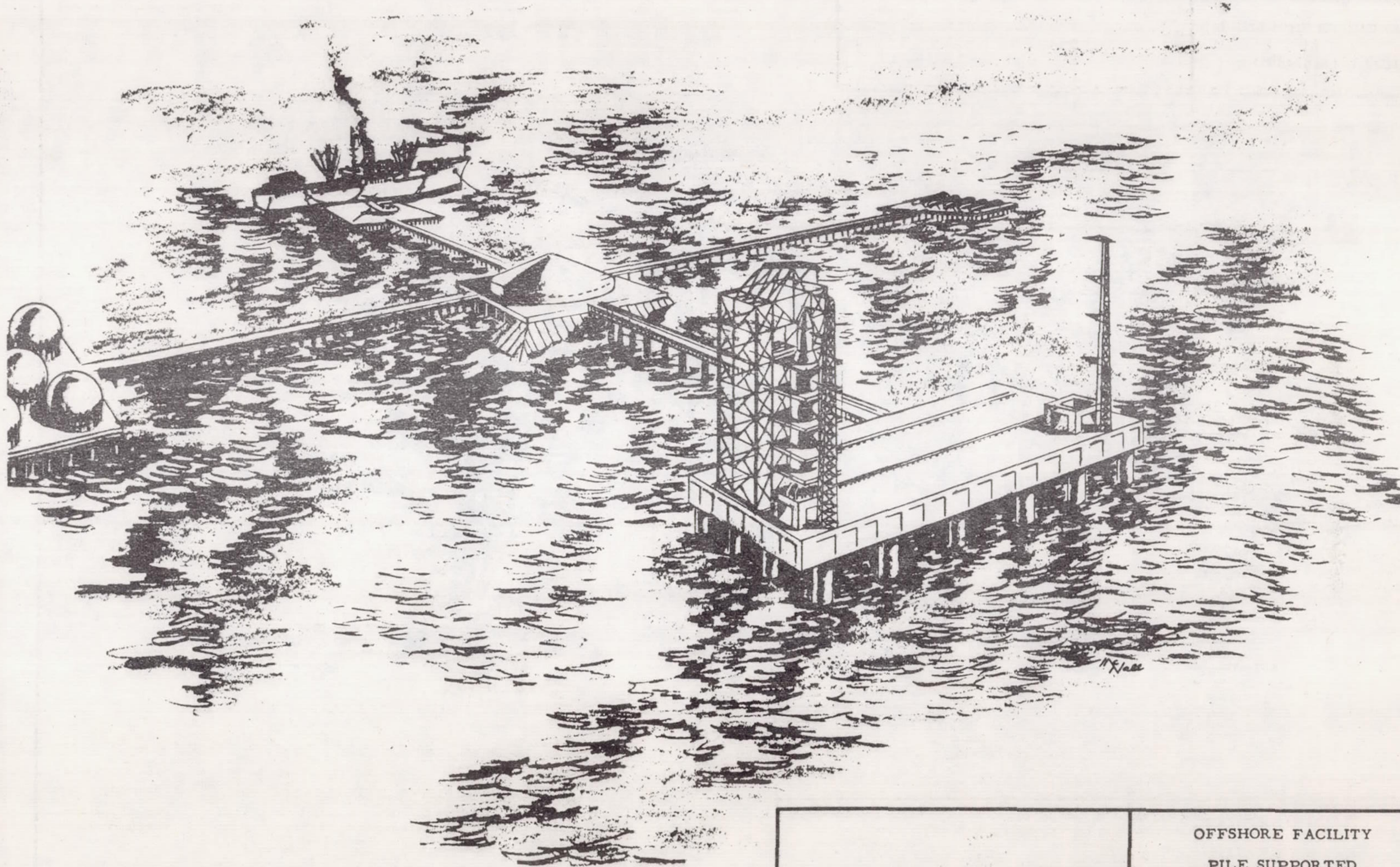
From the foregoing material, it is apparent that these requirements will be a function of where the launch sites are located. It now appears possible to assume that C-3 liquid and solid, and NOVA liquid, facilities may be installed on-shore. The issue regarding solid NOVA is still in doubt. It is important to recognize that the present geographic limits of the Cape must be extended for two reasons, expansion because of the size of the C-3 and NOVA operations and expansion because of the sound level problem. In order to accommodate the increased traffic, operational and facilities problems, some consideration has been given to acquiring a portion of the eastern side of Merritt Island at AMR and to extend the northern boundary of the Cape. The Merritt Island acquisition relates to the need for installing new facilities such as a cryogenic area and a larger industrial area. Associated with this would be the requirement to dredge a barge canal up the Banana River so that vehicles could be delivered adjacent to the newly installed launch sites. The extent of the additional purchases to satisfy the sound level problem is unknown at this time although considerable study has been given to the problems associated with this acquisition. Variously, information has been received that as many as 2,000 separate land owners would be influenced by this purchase. Aside from the processing of internal papers between



SEMI-OFFSHORE FACILITY

PILE SUPPORTED PIER CONCEPT

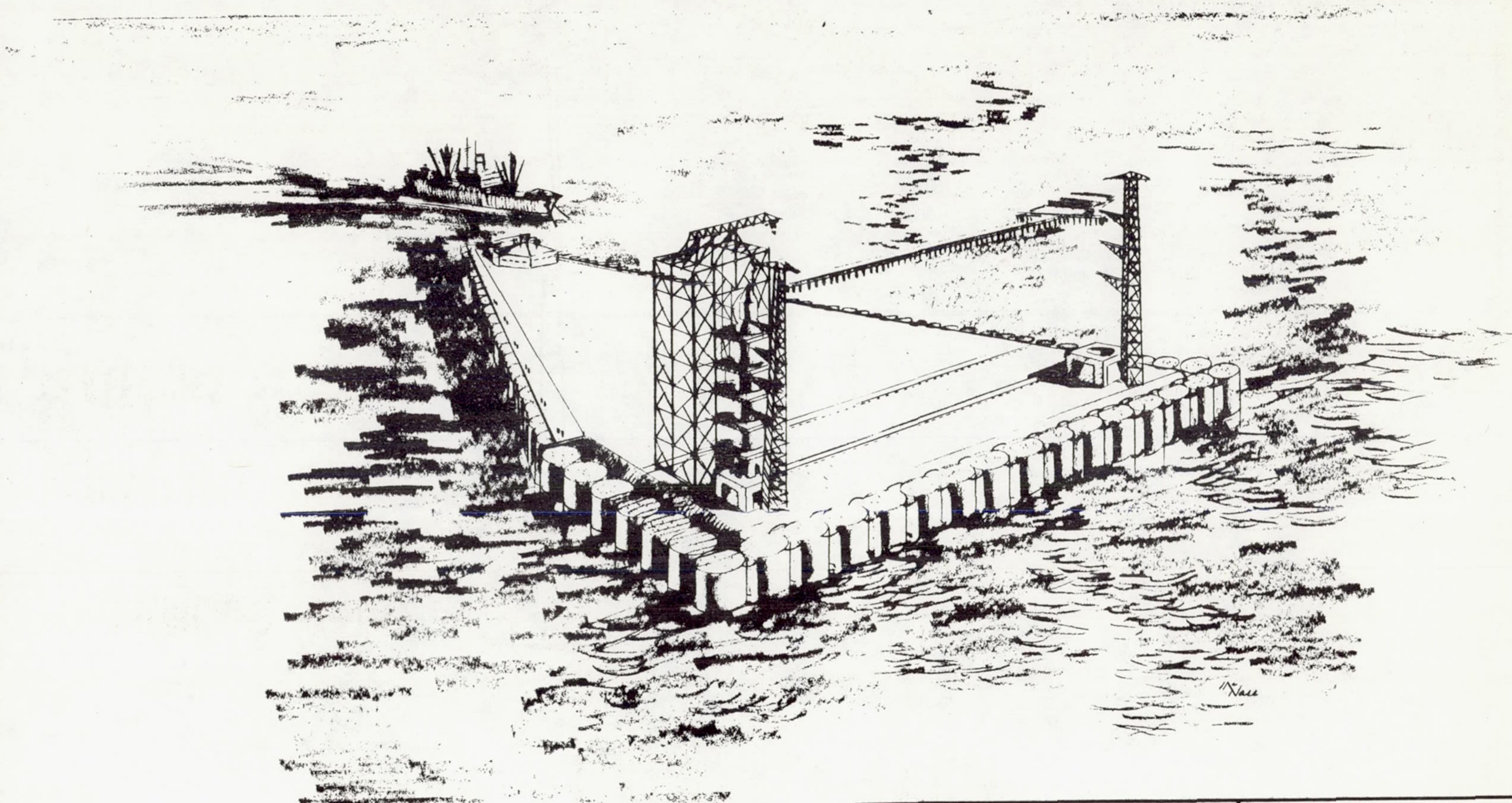
FIGURE 7



OFFSHORE FACILITY

PILE SUPPORTED
PLATFORM CONCEPT

FIGURE 9



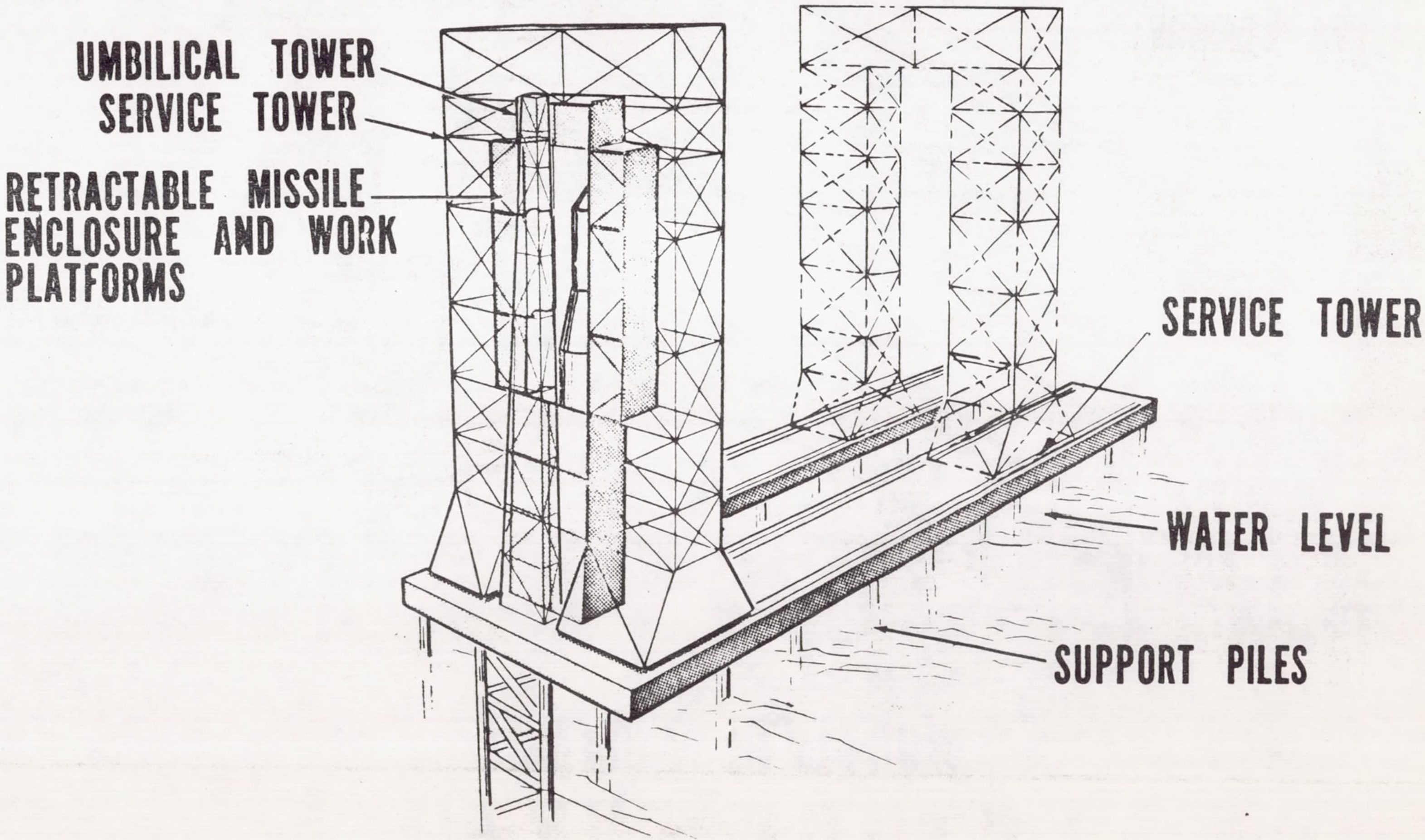
OFFSHORE FACILITY

LAND FILL ISLAND CONCEPT

FIGURE 8

TEXAS TOWER

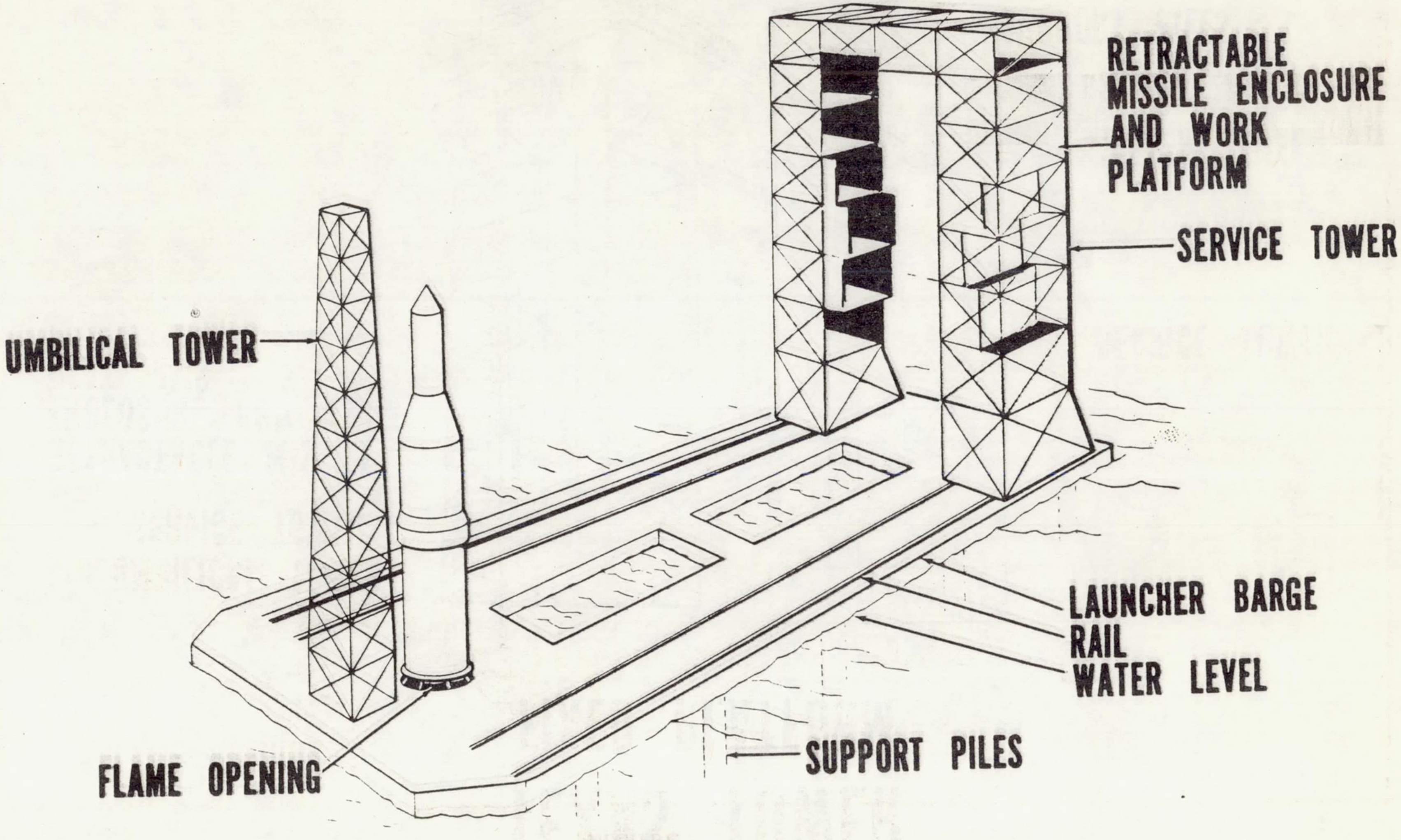
FIXED PLATFORM



FIGURE

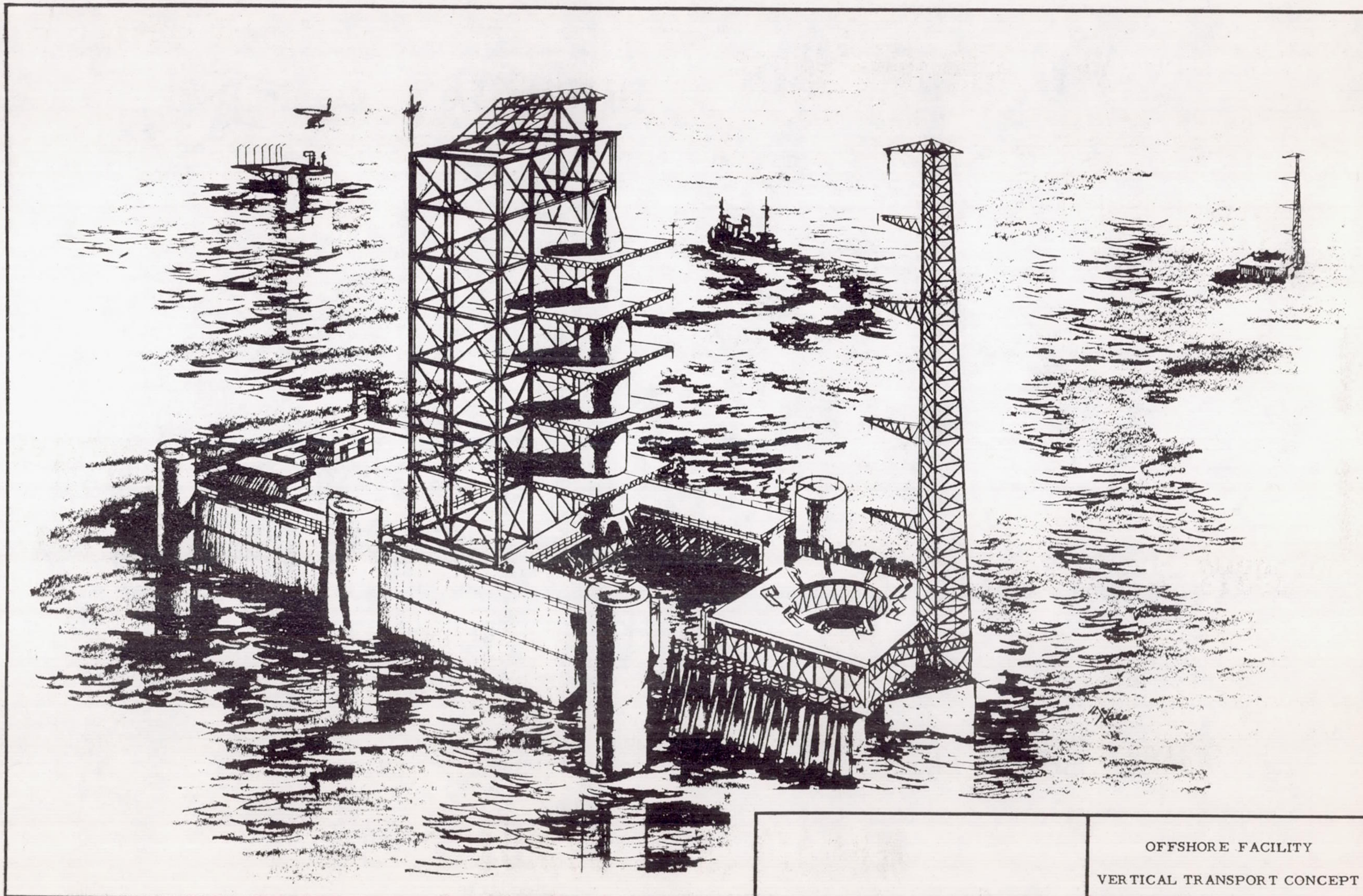
FIGURE 10

TEXAS TOWER
TOWABLE PLATFORM



FIGURE

FIGURE 11

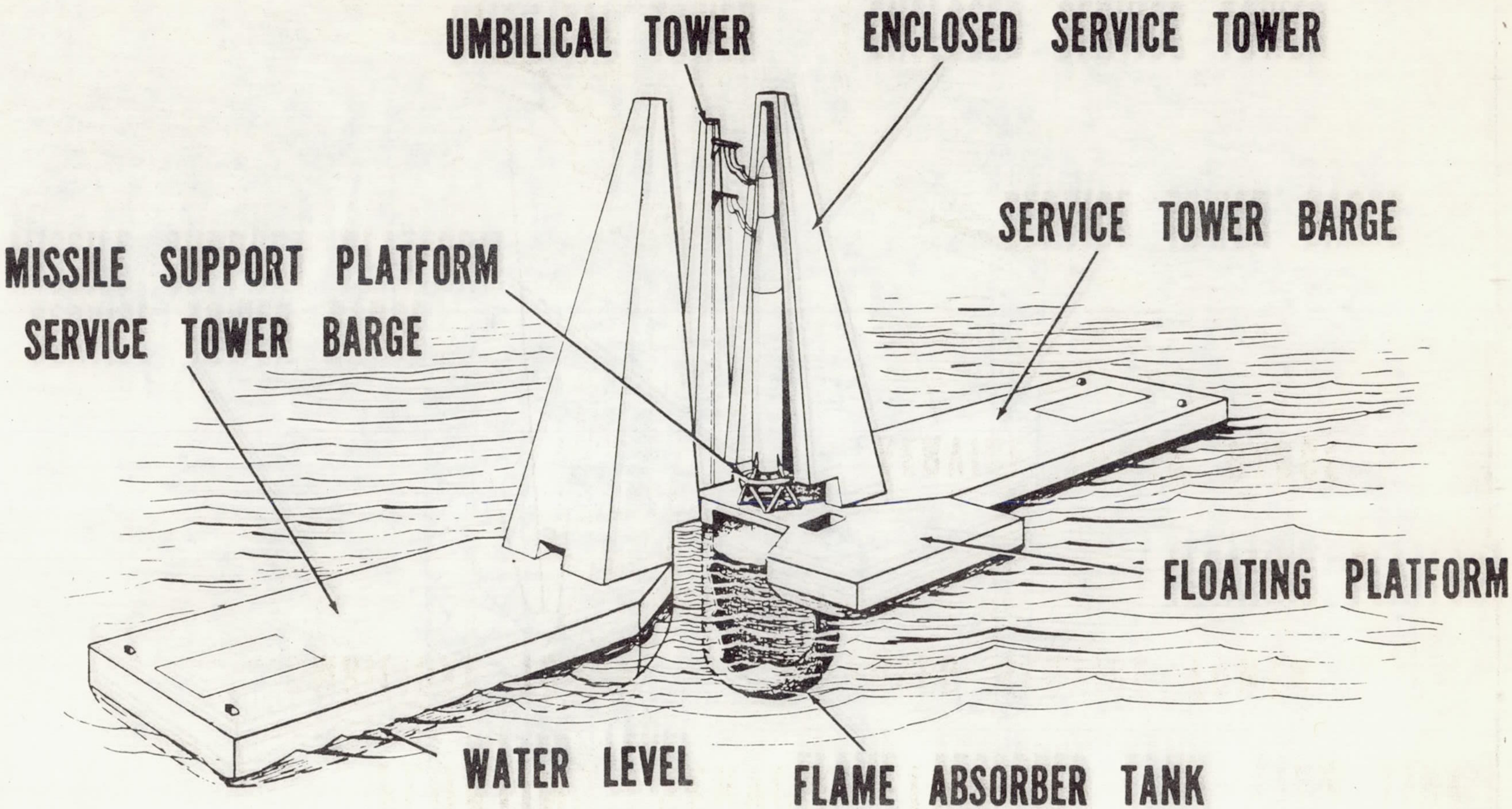


OFFSHORE FACILITY

VERTICAL TRANSPORT CONCEPT

FIGURE 12

FLOATING LAUNCHER PLATFORM

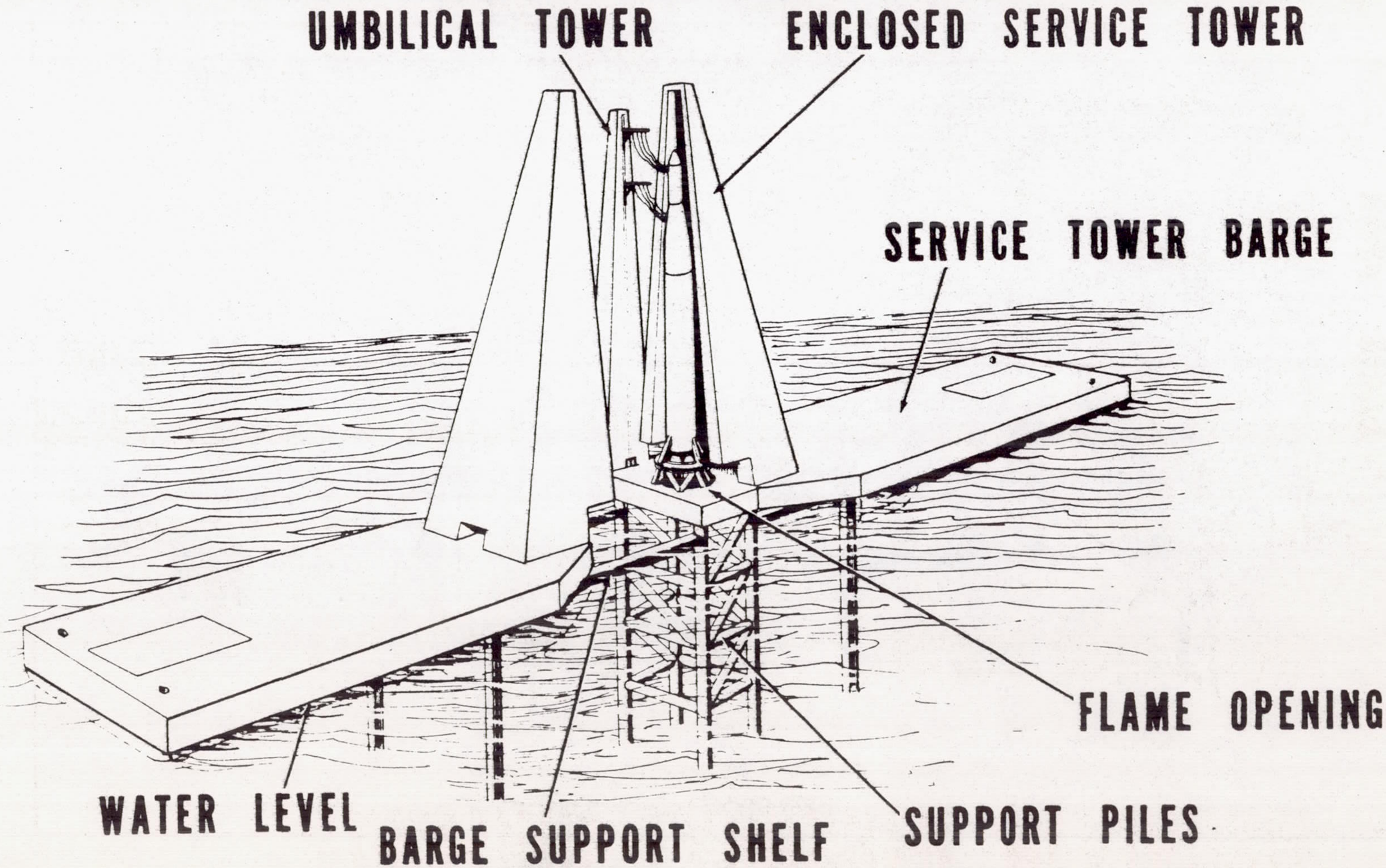


FIGURE

FIGURE 13

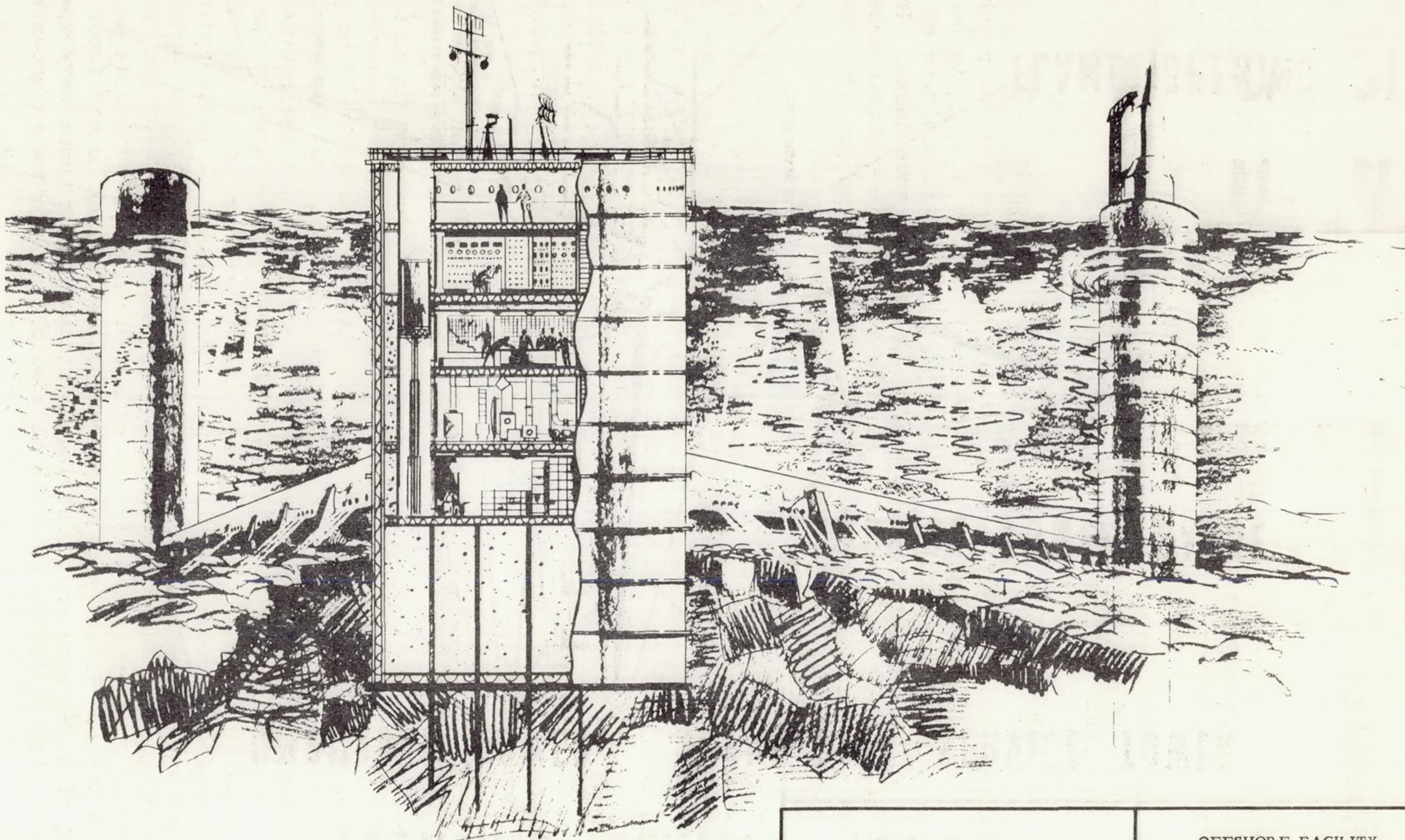
TEXAS TOWER

FLOATING SERVICE TOWER



FIGURE

FIGURE 14



OFFSHORE FACILITY

SUNKEN CAISSON CONCEPT

FIGURE 15

NASA, AMR and the Air Force (i.e. statement of justification, safety studies, facility and instrumentation) certain other steps must be followed in order to acquire the necessary property. These steps are as follows:

a. Submit real estate planning report to Corps of Engineers,
b. Mapping,
c. Tract approval,
d. Title evidence, and
e. Negotiation

Sufficient experience exists in this area to indicate where the trouble spots may lie. As an example, in the case of title evidence, six months appears to be the minimum amount of time possible for acquisition of land parcels but as much as two years has been consumed in some cases. In any event it is to the Government's advantage to at least obtain easements and options so that land costs will be held to a minimum and new commercial construction can be precluded in critical geographic zones.

Two typical approaches were made to the siting of facilities at AMR. They are shown in Figures 16 and 17 . The first figure assumes that C-3 and NOVA would launch on shore. The second figure assumes that C-3 would be on shore and NOVA would be off shore. 115 db sound level limit curves are also drawn to indicate the radius within which Government control would be necessary. Figure 16 also shows two static test positions at the tip of Cape Canaveral. It is considered probable that these facilities would not be installed at AMR. However, pricing for static booster acceptance facilities has been included in the propulsion facilities requirements, with location undefined.

<u>Analysis of Static Acceptance Stand Installation Problems at AMR</u>

It was originally assumed that acceptance facilities might be needed for the 12M pound stage at AMR, depending upon the method of fabrication and shipment of these stages. The study concluded that it would be possible to construct such facilities at the Cape and that their use would not create s serious noise problem. This approach is feasible since the engine blast could be diverted toward the ocean and sound levels cut down by the injection of water into the jet stream. Moreover, since the static facility would be located at ground level, only one-half sphere of sound radiation would exist as contrasted with a full sphere of radiation when the vehicle is in mid-flight. However, installation of facilities at AMR for this purpose would consume important real estate which might otherwise be used for launch sites. It was also concluded that schedules do not favor the combining of acceptance runs with launch stands except under very special conditions. Particularly, it would be possible to perform an acceptance

CAPE & LAND AREA REQUIREMENTS C-3 & NOVA

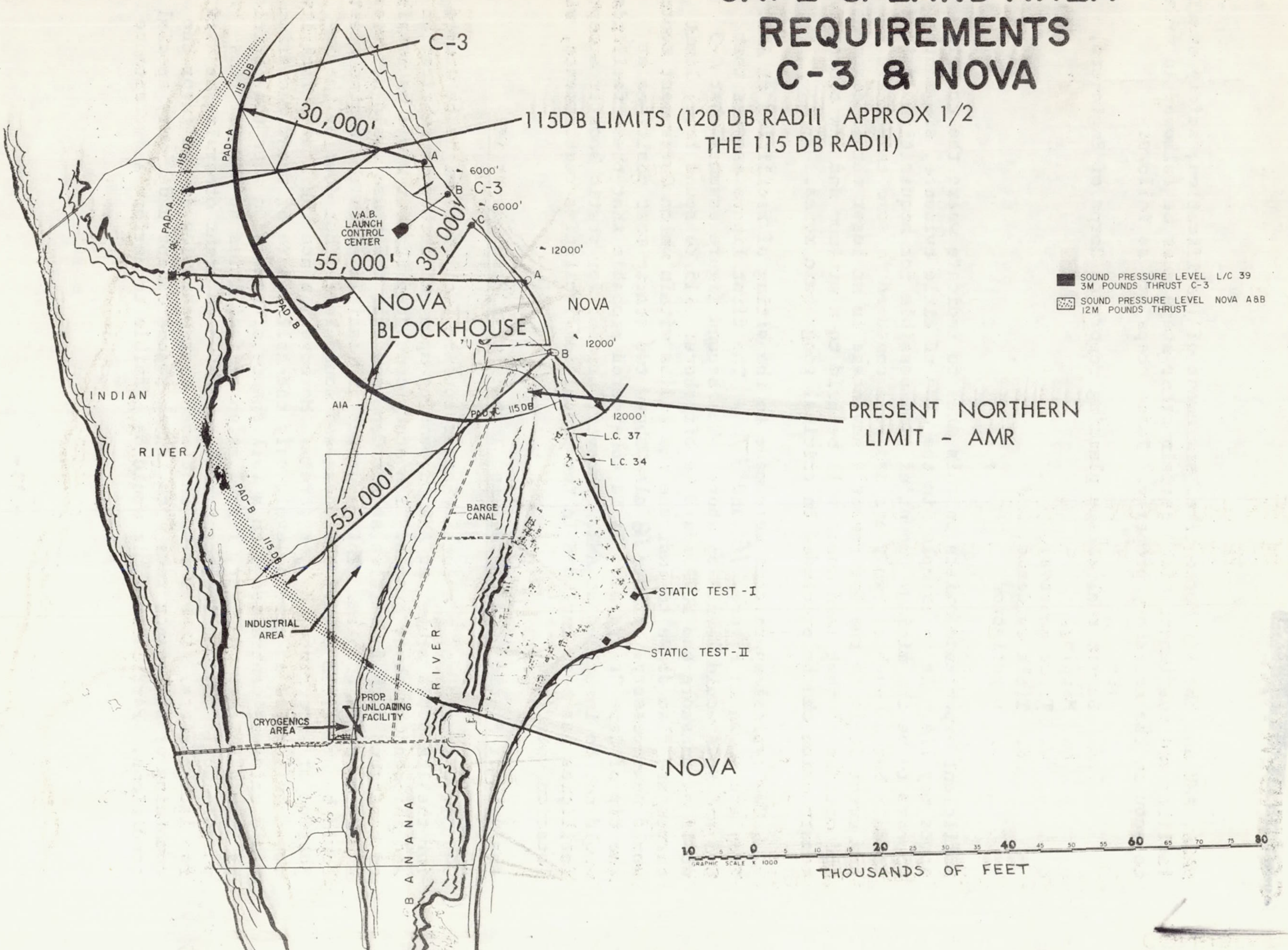
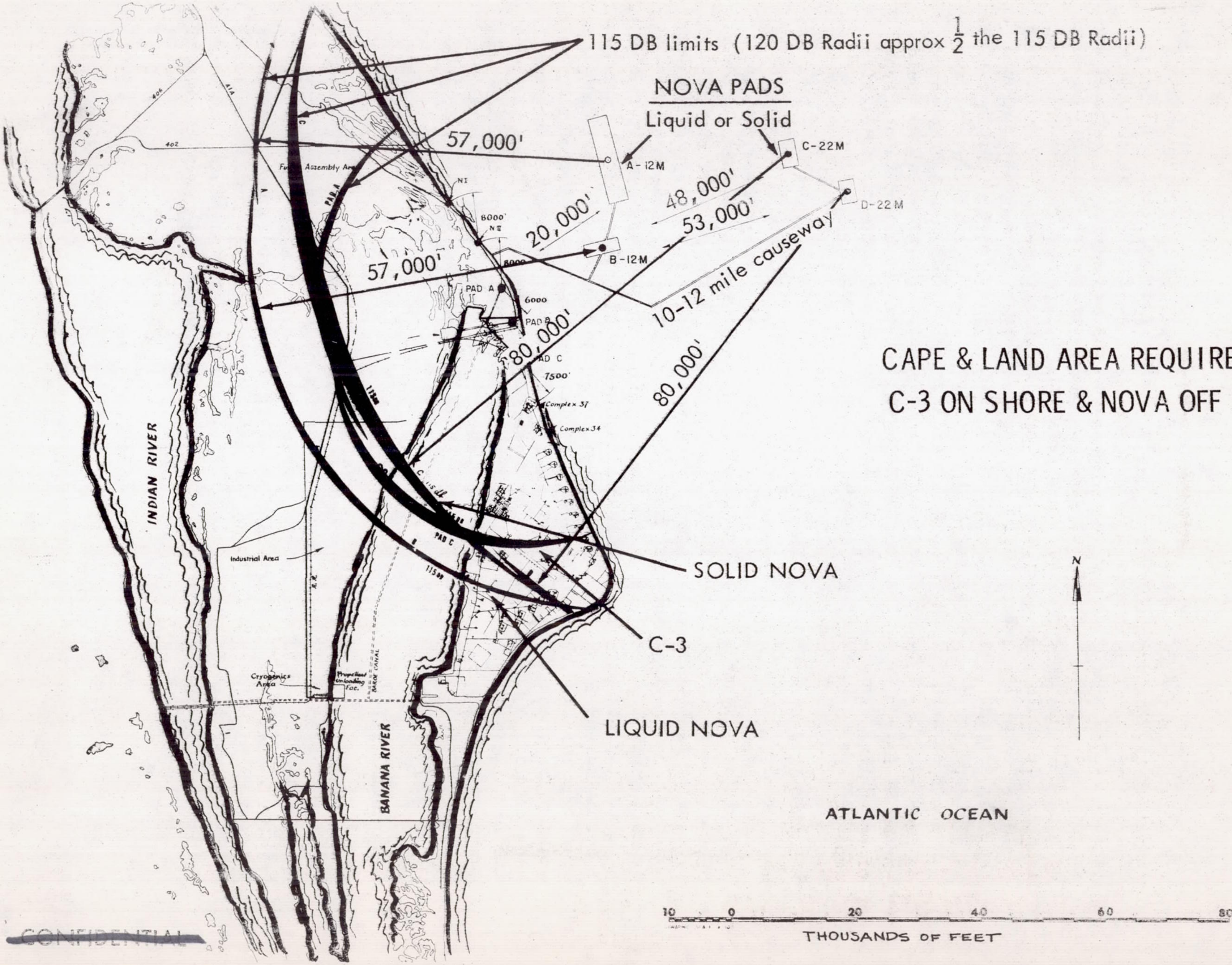


FIGURE 16



CAPE & LAND AREA REQUIREMENTS
C-3 ON SHORE & NOVA OFF SHORE

FIGURE 17

run if the run did not exceed 3-5 seconds. Longer periods of time would require extensive improvements to the deflector and pad area. If a short term run of 3-5 seconds were possible, the next question to be considered is that of the nature of the instrumentation and procedures to be used for acceptance purposes. In the classic acceptance operation, the engine must be shut down, cleaned and rechecked after the acceptance run and prior to launch. It would seem reasonable to consider an arrangement in which this would not occur for a very short term run. In fact, it may be concluded that the initial phase of burning prior to the time that the launch vehicle is released for flight may be looked upon as a form of an acceptance run since its duration is on the order of 3 seconds. If this can be regarded as an acceptance type of operation, the blockhouse instrumentation would not be as extensive as the instrumentation necessary for the normal type of acceptance operation. This matter has sufficient cost and complexity implications to warrant more careful study.

C-3 Facilities

The early portion of this report discussed the "new MSFC approach." This is the concept of vertical assembly and delivery to the pad. Such an approach would be used for liquid C-3. Figures 18 and 19 show typical layouts of facilities and support structures. Solid C-3 will require the construction of stage checkout buildings at the Cape and assembly of the overall vehicle at the pad in a manner similar to that now established for Saturn C-1. The program assumes that a maximum of 6 pads would be constructed, 3 for solid and 3 for liquid. However, the budget was based upon only 4 pads since the initial information available on launch rates indicated that this would provide enough capacity in the liquid and solid cases to accommodate both the launch program and the catastrophy requirements. It was not possible to correct the budgets at the time of submission to show that the quantity now must be considered as 6 pads since 2 pads will be necessary for each type of C-3 to accommodate the launch program, and an additional pad is needed in each case for back-up.

NOVA Facilities

Because of its size, NOVA must be assembled at the launch site. Again, because of size it does not appear to be feasible to consider a gantry which can be moved to the same extent as the gantry now constructed for Saturn. Instead, an enclosed gantry will be used which is hurricane-proof. The gantry*may clam-shell around the vehicle and separate into two pieces which will move short distances prior to launch. The enclosure is necessary because of the nature of the complex operations which will take place over

*Figure 20

C-3

CONFIDENTIAL

L.C. NO. 39
COMPLEX LAYOUT

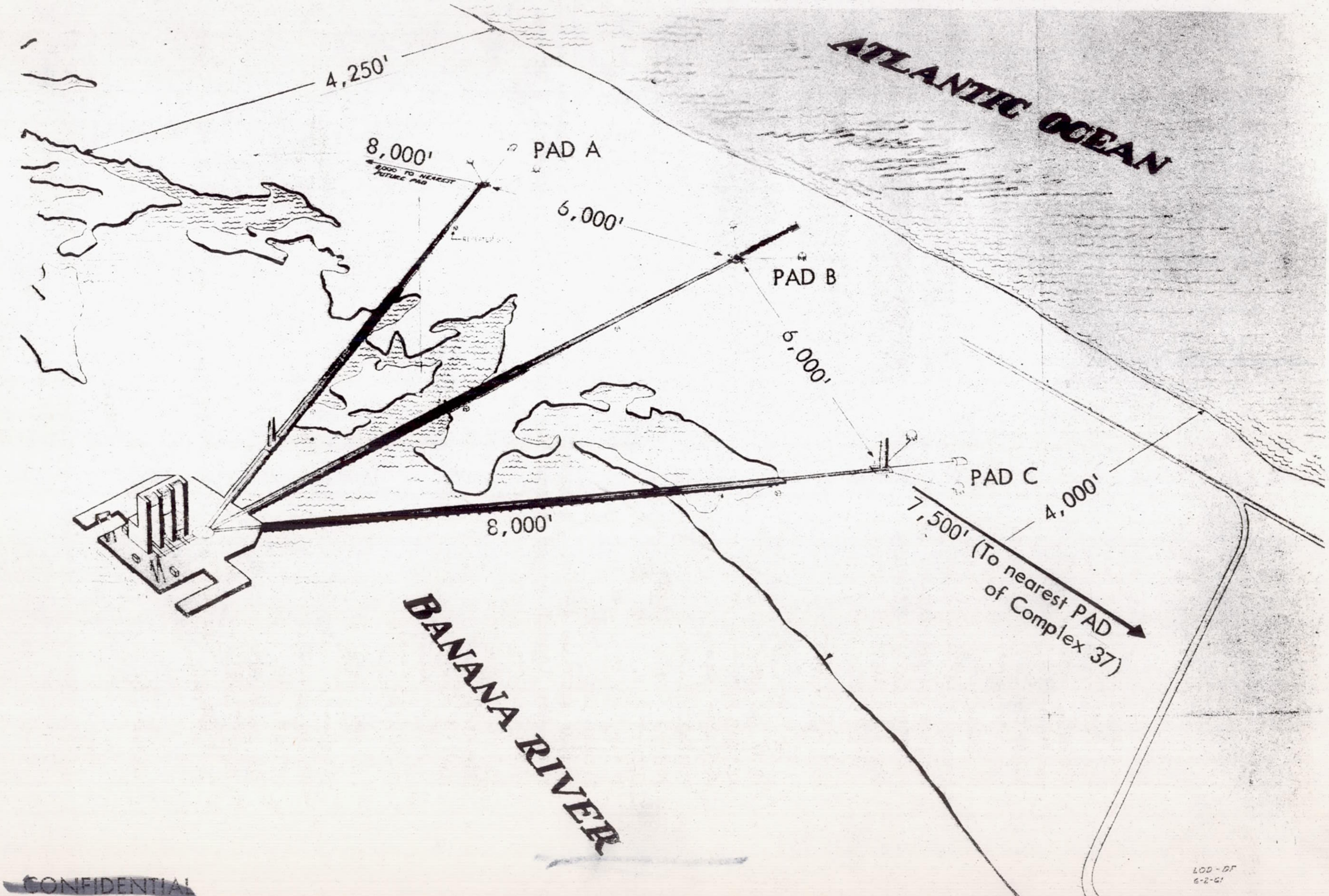


FIGURE 18

-37-

CONFIDENTIAL

~~CONFIDENTIAL~~

L.C. NO. 39

VERTICAL ASSEMBLY BUILDING & LAUNCH CONTROL CENTER

C-3

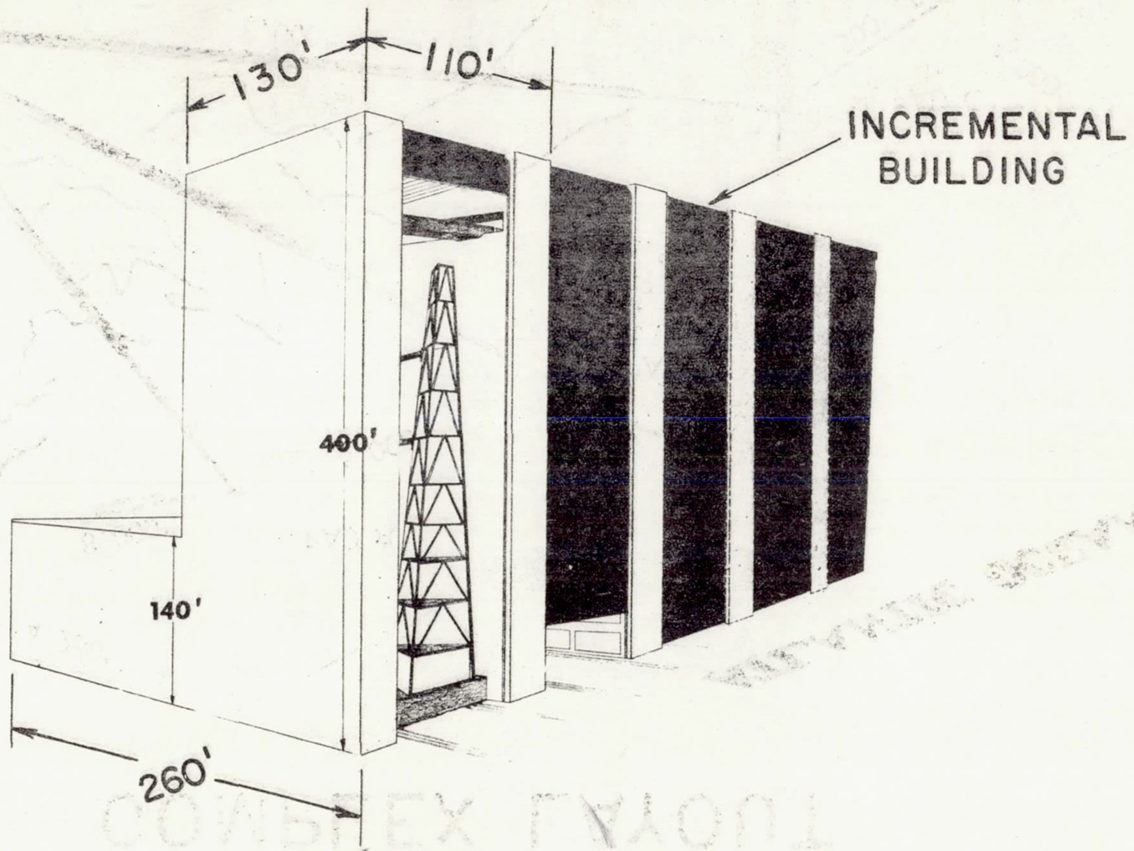


FIGURE 19

CO Restriction/Classification Cancelled

~~CONFIDENTIAL~~

NOVA LAUNCH FACILITY ON SHORE OR OFFSHORE

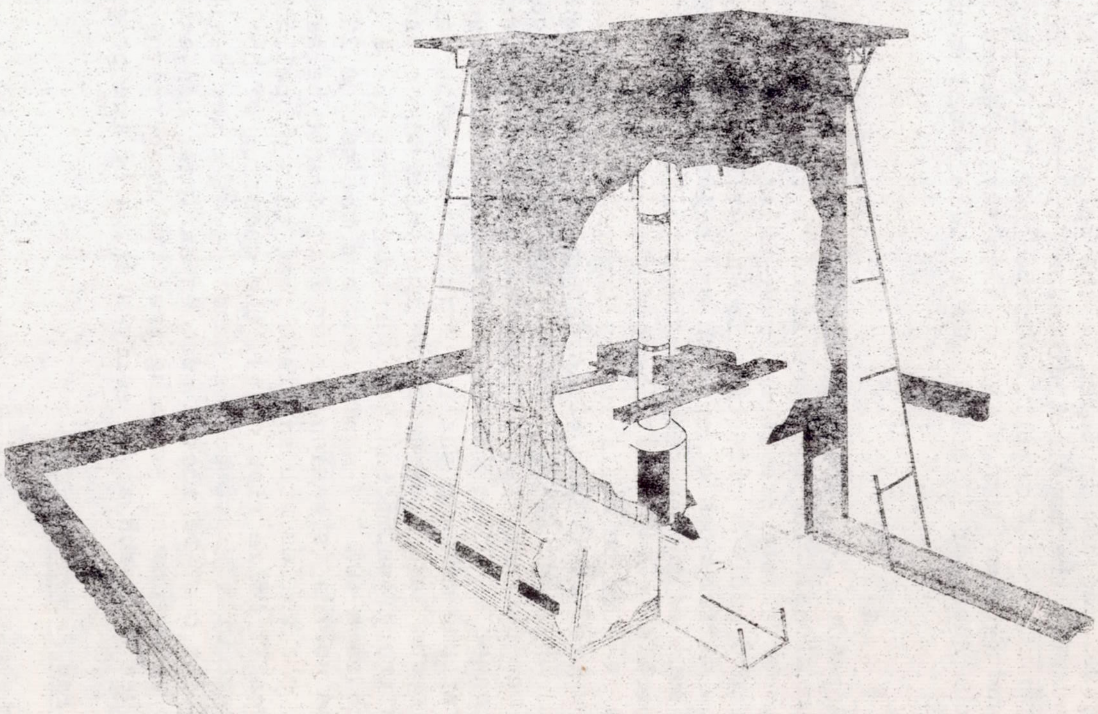


FIGURE 20

long periods of time. A blockhouse will be necessary, located perhaps a mile or more from the pads which it will service. As in the case of C-3, three pads and two blockhouses will be necessary for each of liquid and solid NOVA. Again, the budget submission was deficient by two pads, for the same reason as stated in C-3. Additionally, an oversight occurred in pricing out installations, and the cost of three of the enclosed NOVA gantry structures was not included in the budget. It is for these reasons, coupled with the material discussed in the C-3 portion, that the early paragraphs of this report indicate that the budget may be short between $200 and $400 million. The problem may be eased if solid NOVA can launch from the shore or if solid NOVA is eliminated entirely.

Safety

Appendix C-I took into account more questions than the sound level problem alone. The data contained in this report is also used in assessing what gross safety provisions must exist with respect to explosions, fireballs, and nuclear effects. It was well recognized by the group that serious differences of opinion may exist between liquid and solid vehicle proponents as to the risk levels attendant to their respective vehicles. This problem existed well before the early manned lunar study was established. It was felt to be sufficiently important in Saturn that funds were set aside out of FY 61 and 62 to determine the TNT equivalent of combinations of LOX, LH_2, and RP-1. The program has understandable funding limitations since the desired type of experiment would include full scale tests. Since this cannot be done, more modest but practical experiments will be undertaken at the maximum scaling feasible and with various mixed ratios. Until these tests have progressed to the point where useful data can be analyzed, an arbitrary assumption has been made that the liquid vehicles may contain as much as a 60% TNT equivalent and the solids 20%. Whether the 20% figure for the solids is reasonable or fair cannot be assessed at this time. Although the solids groups claim that this propellant need only be considered as Class II (fire risk only), the question of how the safety personnel at the range will react to the handling of a new device and in such large bulk quantities must be looked upon as at least conjectural at this time. The budget was prepared assuming that the range required handling as an explosive. Any other approach at so early a stage of the program would not be realistic.

Other Pad Requirements

The schedules prepared for the Delta, Agena and Centaur programs indicate additional quantities of vehicles beyond those planned for launching at AMR prior to the formation of this study group. The situation which existed in May of 1961 showed that two Thor pads and six Atlas based pads would be required at AMR into the 1964-65 period. No problem existed in

the case of Thor since two pads are in operation at the Cape. Only five Atlas pads exist at the Cape and action has been started to construct an additional pad, 36B, to take the full work schedule. The planning for these quantities of pads included the best information available on the expected NASA-DOD programs. However, the possible commercial Saturn programs which would be applied to Delta and the additional Delta vehicles necessary for the lunar program support, indicate that consideration must be given to the availability of a third Thor pad at AMR. Such a pad might be available by reassigning one of the two Blue Scout pads now operating at Complex 18. These pads were originally Thor pads and were modified for Blue Scout.

In the case of the Atlas situation, consideration must also be given to the construction of 2 new pads at AMR. Preliminary siting studies indicate that these pads plus their blockhouses might be located south of the newly planned Pad 36B. Whether one or both of these pads must be constructed at AMR will depend upon which of the Agena and Centaur vehicles necessary for the lunar program must be launched at AMR and which of these might be launched at PMR. If the latter launch site could be utilized, it may be possible to achieve these launches from the SAMOS-MIDAS pads which are in various stages of construction at PMR. At present, the two SAMOS-MIDAS pads are in operation and three more are planned for completion of construction in the 1962-63 period. This matter has been discussed with the Space Systems Division of the Air Force and will be investigated further.

Although the above new pad requirements were discussed in the course of this study program, the group was instructed not to include cost figures for these new installations since they could not be considered as uniquely required for the lunar program.

Instead, it was indicated that they must be treated as supporting facilities for a number of NASA operations and should therefore appear in the overall NASA budget.

Launch Facility Schedules and Manpower Considerations

Figure CC 1, SMS Chart 998100 was developed after the establishment of the assumptions listed below:

(a) Assuming that drawings and specifications exist, the minimum time necessary to arrive at the point where construction begins will be 10 weeks. The breakdown of this schedule is as follows:

(1) Time between specification completion and Invitation to Bid - 1 week.

(2) Time between Invitation to Bid and receipt of proposals - 6 weeks.

(3) Time between receipt of proposal and completion of evaluation - 2 weeks.

(4) Time between completion of evaluation and contract award - 1 week.

(b) Some sharing of facilities may exist between liquids and solids. Where this is possible, the schedule covers the construction of these facilities independent of the facilities needed for the unique liquid and solid construction.

(c) Since it is impossible to determine when changes will be made, if any, between liquids and solids, design and construction must proceed in parallel for launch facilities to support liquid and solid C-3 and liquid and solid NOVA.

(d) Because incremental funding is assumed possible, construction was arbitrarily divided into two groups defined as Phase 1 and Phase 2. Phase 1 covers the heavier concrete and steel work, where Phase 2 completes this work and covers the installation of the more complex equipment.

(e) The facility design effort is also divided into two phases, completion of initial design and completion of final design. This permits the pacing of construction with the recent and progressively improved vehicle and spacecraft data.

(f) The procurement of land is to be based upon two major imputs, the land needed because of increased space needs and the land needed because of the sound level problem.

(g) Although it is recognized that vehicle and spacecraft designs will probably not be available until one year has transpired, it is necessary that the facilities design be stabilized as early as possible. For this reason, it is assumed that approximately one-half year after the start of vehicle and spacecraft designs, these programs will establish design control systems. After this point is reached, data supplied to facilities design groups is assumed to be under the control of some type of approval system.

The resulting simplified schedule for the construction of launch facilities is shown in Figure . In the case of C-3, the January 1965 launch date provides a maximum of three and one-half years for the design, construction, and checkout of the facility. For NOVA, the time span for similar events assuming a September 1965 first launch provides for a little over four years. A comparison of some of these times with previous programs shows the following:

Construction Time Only
(Does not include design and systems check)

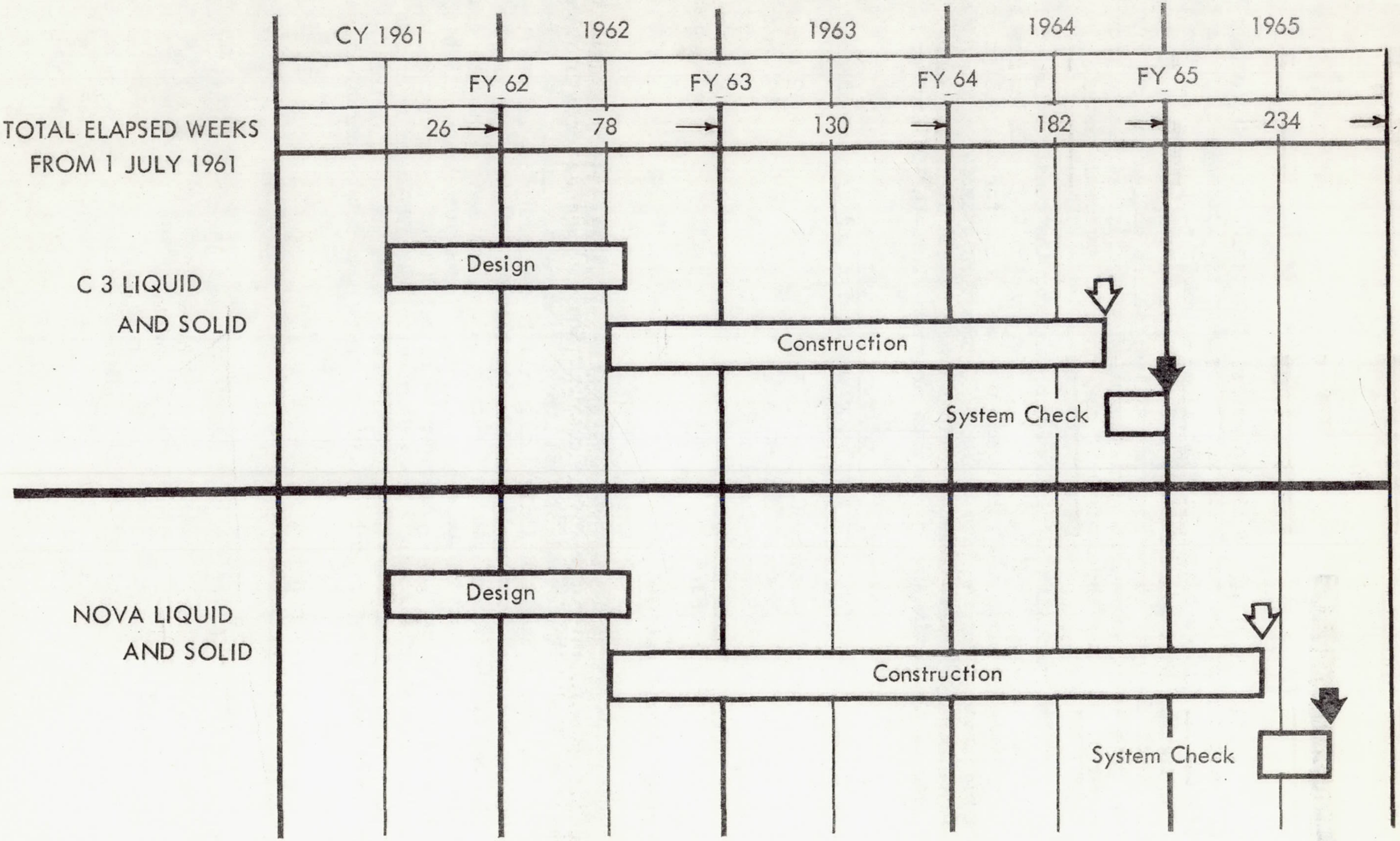
Centaur Complex 36B	52 weeks
Saturn Complex 34	69 weeks
Saturn Complex 37	78 weeks
C-3	104 weeks
NOVA	130 weeks

Manpower Considerations

It is to be expected that a program of the dimensions indicated will require sizable numbers of engineers and construction people, mustered in a very short period of time. The schedules and budgets indicate, roughly, that between 3 thousand and 5 thousand individuals will be necessary in the first year of operation and that this would build up to between 12 and 15 thousand people by the end of the second year. A determination was made as to the practicality of achieving manpower in these quantities. Discussions were held with the Corps of Engineers, Kaiser Steel, American Machine & Foundry Company, Ralph M. Parsons Company, Aetron, the Atomic Energy Commission, the BMEWS Group of RCA, and others. On the average, it appears that the manpower requirements for this program are not unrealistic and that other major programs have met comparable requirements successfully.

LAUNCH FACILITIES

C 3 & NOVA - LIQUID & SOLID



DELIVER VEHICLE TO LAUNCH PAD

COMPLETE SYSTEM CH AND FIRST LAUNCH

FIGURE 21

APOLLO LUNAR LANDING

Ground Instrumentation Study

SUMMARY:

A cursory four week study was performed on the technical, scheduling and funding problems in the area of ground instrumentation associated with a "possible plan" to land a man on the Moon by 1967. Previous studies by STG, Convair and GE were also reviewed for ground instrumentation approaches. It is emphasized the findings of this study are tentative in nature and the most worthwhile use of this report is the identification of critical areas needing further study or consideration. The critical areas are discussed in length in the appendix.

The ground instrumentation approach considered used the following major assumptions:

1. Maximum use would be made of existing and planned NASA and DOD ground instrumentation facilities.

2. Use of existing or planned ground instrumentation would cause only minimal interference with other current or proposed spaceflight programs.

3. All ground instrumentation from launch through recovery would be considered as an entity. Since spacecraft tracking, data and communication requirements are not yet firm, certain assumptions had to be made for a logical analysis.

4. The above and other assumptions used are discussed in the appendix.

It must be recognized the ground instrumentation is being planned for four missions, each having reasonably different requirements and time scales. Despite this fact, a highly efficient and closely integrated ground instrumentation complex is proposed. The four missions are:

1. The Apollo 18 orbit manned mission - starting February 1963.

2. The increased Ranger and Surveyor unmanned lunar missions - starting September 1963.

3. The Apollo orbital and elliptical manned missions - starting October 1964.

4. The Apollo circumlunar and lunar landing manned missions - starting July 1966.

The solution to the ground instrumentation problem is a complex of existing sites at AMR, PMR and the so-called Mercury, Minitrack, and Deep Space facilities. In addition to these, coverage must be supplemented by several shipboard installations and possibly one new ground site. To accomplish this the following major facility additions will be needed:

1. A launch instrumentation complex suitable for Nova must be built. Current indications are that emphasis will have to be on remote controlled launch operations, measurement devices and range safety.

2. To meet the Apollo 18 orbit mission requirements, a current South American Minitrack site (probably Antofagasta) or a geographical "image" site must be heavily augmented and an additional shipboard installation might be desirable for even greater coverage.

3. In conjunction with the above and to handle the Apollo orbital missions, the existing Mercury network must be heavily augmented and updated. In particular a PCM telemetry receiving system, extensive modification to the FPS-16 radars, purchase of a few new FPQ-6 radars, a 2395 MCS receiving capability, a 2113 MCS transmitting capability and several shipboard instrumentation stations are indicated at certain or, in some cases, all facilities. Besides added orbital coverage, the ships will be used in the injection-parking and re-entry-recovery phases of flight. These ships will also be used for similar beginning and ending portions of the mission trajectories described in sections 5, 6 and 7 following. A new integrated control center for Apollo control, ground communications, computation, data processing and command is proposed.

4. The proposed enlargement of the Surveyor program and the increased need for reliability in the manned Apollo mission requires increases in the capabilities of the Deep Space stations. Three additional 85 foot antenna stations with associated electronics appear necessary. These new antennas will have characteristics of coverage, tracking speed and reliability suitable for the Apollo mission, in contrast to current equipment.

5. The Apollo elliptical missions could prove to be the most complex, depending on the particular orbital parameters chosen. Elliptical orbit missions with apogees less than about 8000 nautical miles can easily be handled by the same stations used for the orbital missions described in paragraph 3 above, with a minor ship repositioning. However, elliptical orbit missions with apogees greater than 8000 nautical miles will additionally require Deep Space station coverage of the apogees, providing these apogees happen to fall within sight of the proposed stations. The 8000 nautical mile figure was determined by assumption of certain

parameters. In practice a variation in this figure of between 4000 and 12,000 nautical miles could occur.

6. The Apollo circumlunar and lunar missions can be instrumented using the orbital stations for the first and last 8000 nautical miles of flight and the Deep Space Stations for the total remaining. Several considerations discussed in the appendix, pertaining to television, lunar landing beacons, spacecraft guidance and failure communication might lead to additional facilities needs.

Concerning time phasing of the ground instrumentation, it appears all spacecraft requirements can be satisfied in time to meet the proposed flight schedule. In fact, only the instrumentation facilities needed for the Apollo 18 orbit mission and the Surveyor augmentation can be considered pressing. It is also noted the large "slack" times shown by the SMS computer runs on the Apollo instrumentation facilities are purposeful, since it shows minimal necessary times and allows easy realignment of the networks with changing flight schedule dates as planning becomes firmer.

Extreme caution should be exercised in reviewing the funding. Only the FY 1962 and 1963 estimates have reasonable reliability. The funding shown includes large amounts for the proposed shipboard installations and launch site instrumentation, making the total deceptively large.

In conclusion the most immediate pressing point is the need for good, integrated Apollo ground instrumentation planning. First, a compatible telecommunication system must be planned by considering both the ground and spacecraft portions. Since no Apollo contractor is as familiar with the NASA ground instrumentation as the originating NASA laboratories, it is obvious the responsibility for defining the ground instrumentation and for specifying the parameters for the spacecraft telecommunication systems should be retained in-house. The Convair and General Electric proposals reviewed in the study support this contention. Lastly, it is possible to save significant costs in the future by accomplishing the above planning very early in the program, i.e. immediately.

APPENDIX

Ground Instrumentation

The subsequent material is divided into the following topics:

1. Launch instrumentation
2. Staging and parking orbit instrumentation
3. Final injection instrumentation
4. Orbital flight instrumentation
5. Elliptical flight instrumentation
6. Guidance instrumentation
7. Abort instrumentation
8. Lunar flight instrumentation
9. Re-entry instrumentation
10. Recovery area instrumentation
11. Ships
12. Ground communication
13. Control center

Figure one shows the programs considered in the study and the ground instrumentation networks proposed to support them in time sequence. The additional ground instrumentation facilities needed, with the appropriate time phasing, are summarized in Figure two. Individual discussion of the support planned and the additional facilities is contained in the subsequent sections.

~~CONFIDENTIAL~~

Figure 1

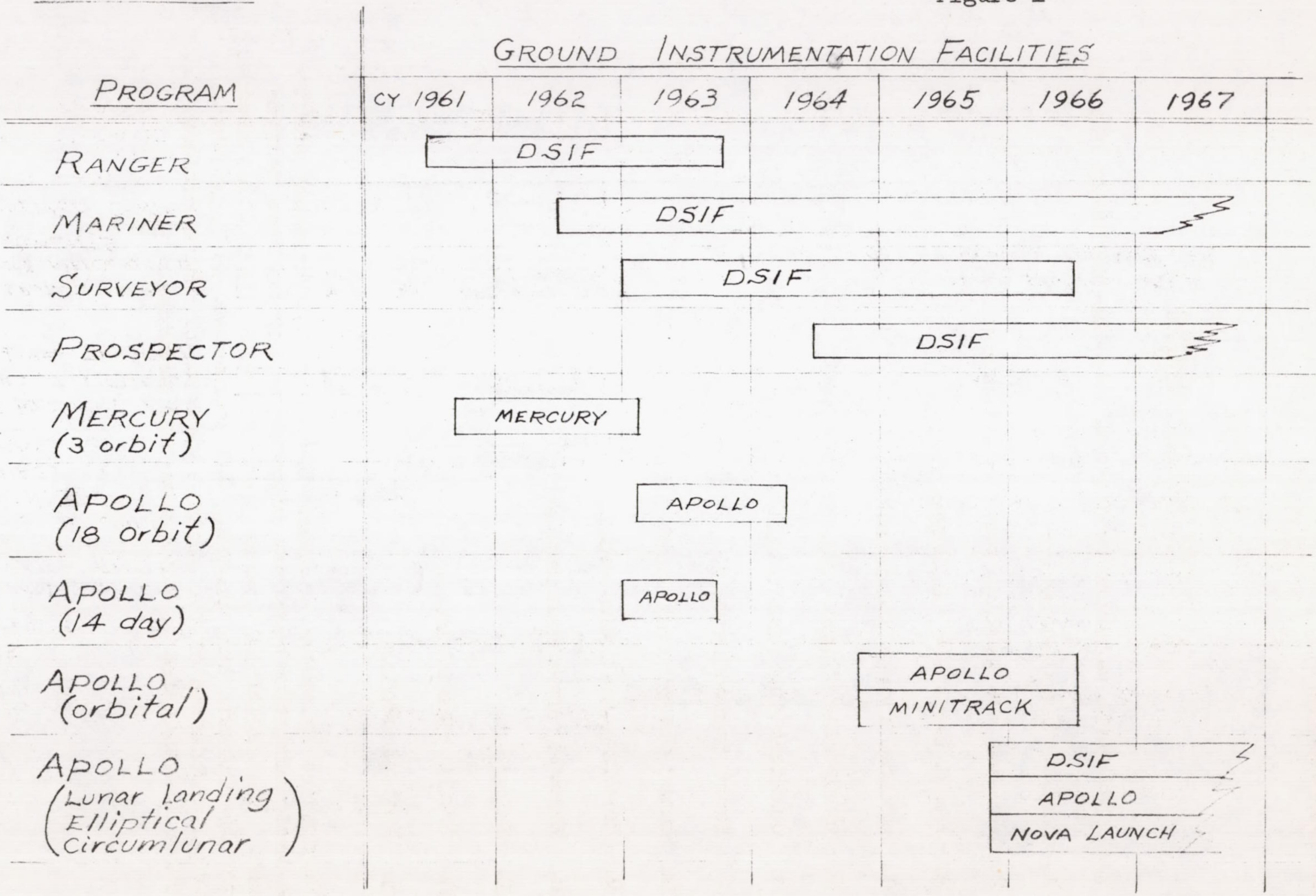
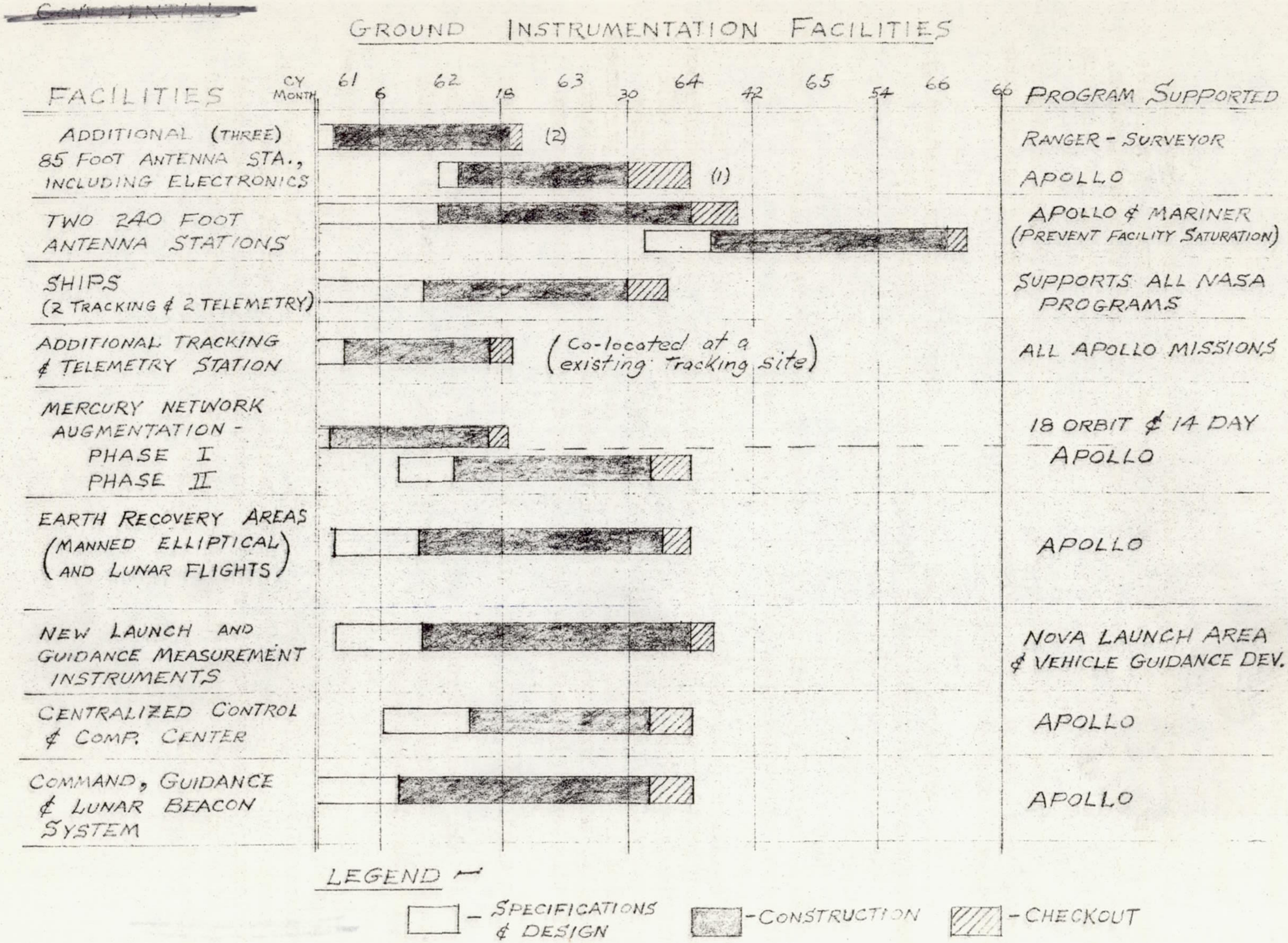


Figure 2

~~CONFIDENTIAL~~



1. Launch Instrumentation

The major assumptions used were:

a. The only problem areas considered would be those created by using a Nova booster vehicle. This implies the C-1 and C-3 vehicles could be launched from the existing and planned AMR instrumentation, with only possible augmentations for the increased volume of firings.

b. The Nova launch area would be located within twenty miles of present AMR limits. The problems associated with further separations were also discussed briefly.

c. The pre-launch, on-pad and firing aborts would be handled by the spacecraft propulsion system as described in section 7.

d. The booster guidance would be all inertial.

e. The immediate Nova pad area would be extremely hazardous due to noise, explosion and possibly nuclear hazards.

Considering first the instrumentation on the pad itself, the primary problem will be a massive data retrieval. Once the completed vehicle is erected and fueled, extremely large amounts of data will be required for ground checkout and countdown procedures. If the pad area is as hazardous as anticipated, many functions, now performed manually, will have to be performed by remote control. Associated with this would probably be an elaborate closed circuit TV system.

To meet this heavy data flow, several approaches are indicated:

a. All measurements would be digitalized at the source, if not naturally in digital form. Commutation and sub-commutation of many inputs should be possible.

b. The digital measurements would be multiplexed and transmitted via microwave links to the launch control point. The use of RF transmission in preference to use of co-axial cables seems apparent, although care must be exercised to eliminate flame attenuation problems. This preference for RF transmission is based on the need for wide bandwidth data links over many miles, coupled with a high degree of flexibility needed in vehicle development phases.

c. The digital system should be completely compatible with data processing and computer systems. A majority of the data displays at the launch control center and probably many of the minor decisions will be accomplished automatically by these devices. The level of raw information from the vehicle will be too great for assimilation by humans during the relatively short time period of critical launch phases without computer aid.

A large quantity of "ground checkout" equipment will be needed for the various vehicle stages and spacecraft. No critical areas are apparent in this field, although stricter control to cope with the radio frequency interference problem is vital, especially if RF data transmission is used.

Concerning metric measurements, the major tracking requirements will be for vehicle development and range safety, since it was assumed the booster guidance was inertial. Under the further assumption that the launch pad is within 20 miles of the present AMR rangehead, the only additional tracking devices needed appear to be the normally used optical theodolites and cameras, since the existing range instrumentation can see the craft after it rises a few thousand feet. It appears sufficient accuracy of tracking can be obtained for vehicle development purposes from the planned MISTRAM tracking system, with existing FPS-16/FPQ-6 radar tracking as a back-up for range safety. In any event, the use of the current AZUSA tracking system at AMR seems unnecessary.

As for range safety, there appears to be no serious launch problems. A new command destruct transmitter may be required nearer the pad for continuous ability to destroy the vehicle from liftoff. It is obvious the remaining coverage can be accomplished from the AMR, once the vehicle has risen less than a mile off the pad.

Considering range safety during flight, it appears for many firing azimuths of interest the booster and subsequent non orbiting stages impact in the Atlantic Ocean. Further detailed study is needed to insure adequate safety and to define precise firing azimuth limits. In general this problem appears very similar to the Saturn's range safety problems. On the other hand, orbital stages must overfly Africa on the way to the Moon, and it is most probable the upper stages can have an impact point in Africa due to certain type propulsion failures in previous non-orbiting stages. This type hazard is a fact of life and little can be

intelligently done about it. However, the hazard to life is considerably less than the possibility of accidental failure of a commercial jet aircraft while landing at New York City.

If the assumption of a Nova launch pad located no further than 20 miles from AMR is incorrect, further complications arise. Many instrumentation functions, especially range safety, will have to be duplicated. In particular the metric measuring system is fairly critical, but the specific equipment needed depends on exactly how far from the range the pad is located. For pad locations from approximately 20-70 miles, there is a probability two FPS-16/FPQ-16 radars might be needed <u>if</u> the vehicle is traveling towards the areas covered by the range. For similar conditions and a 70-150 mile separation, a third radar might be required. For separations greater than 150 miles, a precision metric measurement system like MISTRAM might possibly be required in the launch area, assuming very accurate trajectory information is desired by the vehicle development group. Such instrumentation is exceedingly complex and expensive. (The original MISTRAM installation at the Cape is estimated at 30 million, not including land and peripheral costs. However, subsequent installations should be only about half this cost.) Lastly if a Nova launch site is chosen which can make little or no use of existing AMR instrumentation, a new launch range must be created. No cost could be estimated for such a Nova range until its geographical location is better specified; however, the cost could be enormous. In conclusion it would appear the Nova launch pad should be located as close to the present AMR as feasible for maximum reduction of ground instrumentation problems.

2. Staging and Parking Orbit Instrumentation

The problems of this stage of flight are very complicated and it was not possible to make any logical assumptions, other than the fact a parking orbit would be necessary to provide a reasonable firing window without sacrifice of booster payload capability. It is obvious the azimuth of launching and the length of the parking orbit varies rapidly with the time of day for a given flight time from the Earth to the Moon. Further, the change in the apparent declination of the Moon causes a longer term change in the above parameters. As an illustration, in four hours the launch azimuth can change from about 75 degrees of North to 110 degrees of North for a lunar declination of 18 degrees South and a 3.5 day flight time. The vehicle burning and coast angle correspondingly goes from about 91 degrees to 40 degrees. There is also a shift in the injection point on a daily basis of approximately 400 nautical miles due to apparent declination change of the Moon.

It would appear almost complete coverage of this phase of flight would be highly desirable, both from a spacecraft and a launch vehicle development point of view. Complete coverage refers to telemetry, voice, command and similar systems; however, complete metric coverage will not be provided. Enough metric coverage should be available to determine vehicle performance and the orbital parameters of the parking orbit. Metric coverage for vehicle performance should cover the stage firings and separation periods and should be of high instantaneous quality. Metric coverage of the parking orbit should occur as close to insertion as possible, but the instantaneous measurement accuracy need not be necessarily high, since data smoothing may be employed.

To obtain the above coverage, it appears one can launch over the "Mercury slot" of 73 degrees launch azimuth or the "AMR slot" of 110 degrees. The coverage problem is illustrated in figure 3 for a 100 nautical mile vehicle altitude with a 5° station elevation angle. It is important to note that two ships are required in either case for complete coverage, but it appears neither of these ships may need be equipped with tracking devices. However precise Nova trajectories are needed before it can be specified as to whether or not a tracking capability is needed.

The problem of launch window becomes very evident from figure 3. One must wait to launch until the correct firing azimuth corresponds to

Figure 3

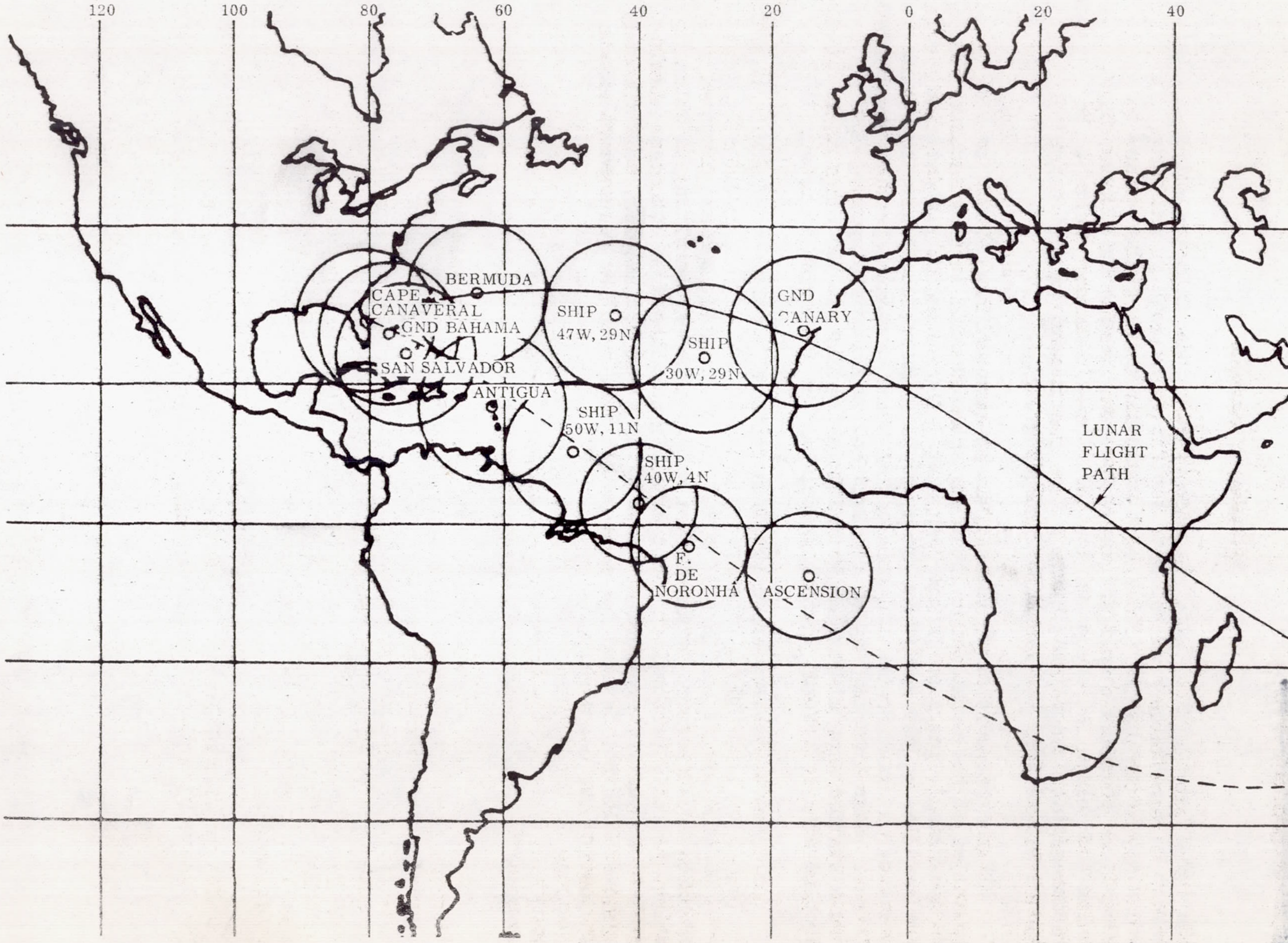


Figure 3 Launch Tracking Stations

that of a "slot". The "slot" is also fixed by the fact the ships cannot be repositioned at the rate the firing azimuth is shifting. It would appear the use of either slot would limit the firing window to roughly an hour and a half per day. One could double this window by using both slots, at a cost of two additional "telemetry ships". No recommendation can be made until a firm requirement is stated for a launch window from the launch operations group.

If the "Mercury slot" is used, it appears an FPQ-6 should be installed at the Grand Canary station. This station is very similar to Ascension's position in the "AMR slot". Depending on the detailed trajectories of the Saturn and Nova, these stations could give important tracking coverage to the final injection phase or post injection phase of flight. Such tracking may be required for vehicle development, down range station acquisition, abort and flight guidance. No other major problem area is evident in this phase, but the following is noted:

a. Abort problems are covered in section 7.

b. The use of an "INVERSE DORA" ground tracking system, proposed by MSFC, would require triangulation sites, probably resulting in extra ships. If this proposal is adopted for Saturn, the Nova situation should present no particular problem. However if it is not adopted, this tracking system should not be used for Nova unless some peculiar requirement exists to justify the complexity.

3. Final Injection Instrumentation

Preliminary analysis shows the final injection point for lunar trajectories will generally occur over the Atlantic. For the Mercury slot the injection will occur before the Canary Island station and for the AMR slot before Ascension. Telemetry, communication and command coverage can be provided as discussed in the previous section and shown in figure three. Metric coverage of the injection should be provided for vehicle evaluation. It may appear possible to accomplish this coverage from existing land sites for both the lunar and orbital type missions. In actuality this may not be possible, thereby requiring ships with tracking capability. The quality of tracking must be high.

In addition to the above, the spacecraft requirements will require some metric tracking after injection to immediately establish an orbit for:

a. Establishing if a satisfactory orbit was achieved for abort purposes (see section 7)

b. Computing acquisition data for subsequent stations.

c. Performing a midcourse maneuver (see section 6).

This measurement requirement of the spacecraft trajectory after injection can possibly be met with the same equipment and station(s) used for covering the injection thrust period for vehicle development. However, due to the changing range and azimuth of the injection point with launch time, the length of thrust period and the limited station coverage possible of a 100 nautical mile orbit, additional facilities may be required. Fortunately there are some existing stations further down range which might provide the needed coverage in many situations if certain reductions in the spacecraft requirements can be tolerated. It is felt the above problem may not be too bad, but not enough information is currently available to support such a contention. Further detailed study of this whole area is needed.

4. Orbital Flight Instrumentation

After final injection, certain Apollo missions will have an Earth orbital trajectory. The orbital height of such missions has not been firmly set, but it will probably be less than 300 nautical miles. Only Saturn and Nova booster missions were considered.

The main problem with the orbital missions is the amount of communications and tracking coverage required. The following assumptions were used:

a. A circular orbit of 300 nautical mile height and an elliptical orbit with a perigee of 100 nautical miles and an apogee of 260 nautical miles were analyzed.

b. An inclination of 33 degrees.

c. Station coverage down to 5 degrees elevation angle.

Figures 4A and 5A show the coverage for the current Mercury stations for the first eighteen orbits. The charts have the orbit numbers plotted as the abscissa and the time of coverage of each station in minutes as the ordinate. Figures 4B and 5B show the coverage of stations in other locations. Figure 6 is a coverage summation of various combinations of stations for the orbits which appear critical. It was assumed if coverage of a particular orbit was greater than 20 minutes, it was adequate, and the orbit was not considered further. Orbits with coverage less than 10 minutes were considered critical. Similar charts are included in the General Electric study. The large difference in coverage between the GE and this study is due to different assumptions for the orbital parameters and stations. A further breakdown was made on coverage time over stations with current tracking capability, but this chart was not included.

It is hoped readers of this study suppress the apparently insatiable desire to become armchair ground instrumentation planners. Although it is valid to pick any combination of stations on the charts and arrive at an "optimum" coverage, there are other considerations of a detailed nature and still others inter-related to different NASA programs which must be included in actually picking the optimum sites.

From the coverage charts, the critical orbits can be eliminated by a station located in or near Chile or its geographical image, south of Japan. It may be desirable to have ground instrumentation at both locations, possibly one of the two stations being on a ship. At one of these locations, it appears particularly desirable to have a C band tracking capability for orbit updating, especially in view of orbital degeneration in the 100 mile perigee case of the proposed elliptical missions.

MERCURY - 300 N/M - 18 ORBITS - 33° INCLINATION

Figure 4A

* TIME OVER STATION

--- ORBIT NO ---

STATION	NO	CODE	STATION LATITUDE	LOCATION LONGITUDE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
CAPE - FPS-16	1	CAFPS	28°28'N	80°34' W	5	9	9	10	6									8	9	9	10	10	6			
CAPE - XNI	1	CPXNI	28°28'N	80°34' W	5	9	9	10	7									8	9	9	9	10	7			
GRAND BAHAMA	1a	BAHMA	26°40'N	77°21' W	6	9	9	9	7									9	10	9	9	9	7			
GRAND TURK	1b	DGRAND	21°28'N	70°09' W	6	7	8	10	7								8	9	8	7	8	10	7			
BERMUDA (1&2)	2	BMUDA	32°21'N	64°40' W	9	10	9	7									4	7	9	10	9	7				
ATLANTIC SHIP	3	ASHIP	28°00'N	40°00' W	9	10	9									7	9	9	9	10	9					
GRAND CANARY	4	GRCAN	27°43'N	15°36' W	10	9									7	9	9	9	10	9						
KANO, NIGERIA	5	KANOO	11°34'N	8°16' E	9	9							7	10	6			4	9	8						
ZANZIBAR	6	ZNBAR	7°19'S	39°19' E	9	8				1	9	8						9	8				1			
INDIAN OCEAN SHIP	7	ISHIP	28°24'S	73°42' E	10	9	8	9	9	6							7	10	9	8	9	9	6			
MUCHEA, AUSTRALIA	8	MUCHA	31°36'S	115°55' E	9	10	9	1									7	9	9	10	9	1				
WOOMERA, AUSTRALIA	9	WOMER	31°12'S	137°06' E	9	9	4									7	10	9	9	9	4					
CANTON ISL.	11	CNTON	2°47'S	171°41' W	9	9						7	9	4				9	9							
KAUAI, HAWAII	12	KAUII	22°09'N	159°38' W		8	9	8	8	9	9	4									8	9	8			
POINT ARGUELLO, CAL.	13	ARFPS	34°35'N	120°25' W	6	10	9	10	8											7	10	9	9	8		
GUAYMAS, MEXICO	14	GAYMA	28°00'N	110°50' W	10	9	9	9	8										7	10	9	9	9			
W.S.M.R., N. MEX.	15	WSFPS	32°22'N	106°23' W	9	10	9	9	5										6	9	10	9	9			
CORPUS CHRISTI, TEX.	16	CCRIS	27°40'N	97°46' W	10	9	10	9	4									3	9	10	9	10	9	4		
EGLIN, FLORIDA	17	EGLIN	30°27'N	86°48' W	4	10	9	9	7									6	9	10	9	9	7			
							20			16	18	19	16	14	13	23			20							

* To nearest minute
* From computed data (GSFC) 31 Mar 1961

STATIONS IN ADDITION TO THE MERCURY NET

MERCURY 300 NM - 18 ORBITS - 33° INCLINATION PERIOD 99 MIN.

TIME OVER STATIONS*

Figure 4B

STATION	NO.	CODE	STATION LATITUDE	LOCATION LONGITUDE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
					-- ORBIT NO. --																					
SANTIAGO, CHILE	MT	SNTAGO	33°9'S	70°40'W						8	9	10	9	8								8	9			
LIMA, PERU	MT	LIMAPU	11°47'S	77°35'W					9	8	3				7	10	4							9	8	2
QUITO, ECUADOR	MT	QUITOE	0°37'S	78°47'W					8	9	3					8	9						8	9	4	
JOHANNESBURG, S.A.	MT	JOBURG	26° 2'S	28°14'E		7	10	9	9	9	9	2								7	10	9	9	9	9	2
ASCENSION ISLAND	AMR	ASCEN					8	9	2			2	8	9							9	9	2			
ANTOFAGASTA, CHILE	MT	AGASTA	23°37'S	70°16'W						6	9	8	8	9	9	5								7	9	8
JAUN FERNANDEZ ISL.		FRDEZ									6	9	10	9	9	4									6	9
SAN SALVADOR ISL.	AMR	SADOR			4	8	8	10	7								7	5	10	9	8	9	9	7		
ST. VINCENTS ISL.		SVINC			6	9	9								9	9	7	4	6	9	9					
BLOSSOM POINT, MD.	MT		38°26'N	77°05'W																						
FT. MYERS, FLA.	MT		27°30'N	80°06'W																						
ANTIGUA ISLAND	MT		17° 9'N	61°47'W																						
SAN DIEGO, CAL.	MT		32°35'N	116°59'W																						
E. GRAND FORKS, MINN	MT		47°42'N	92°00'W																						
ST. JOHNS NFDLD.	MT		47°30'N	52°36'W																						
FAIRBANKS, ALASKA	MT		44°57'N	147°42'W																						
SO. ENGLAND	MT		51°30'N	0 °E/W																						
WOOMERA, AUSTRALIA	MT		30° 6'S	136°47'E																						

* To nearest minute
* From computed data (CSFC) 31 Mar 61

P A
MERCURY - 100/260 N/M - 18 ORBITS - 33° INCLINATION - PERIOD ≃ 95 Min.

TIME OVER STATION*

----- ORBIT NO. ------

Figure 5A

STATION	NO	CODE	STATION LAT.	LOCATION LONG.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
CAPE - FPS-16	1	CAFPS	28°28' N	80°34' W	3	4	5	5	3										4	5	4	4	4			
CAPE- XN1	1	CPXN1	28°28' N	80°34' W	3	4	4	5	3										4	4	4	4	4			
GRAND BAHAMA	1a	BAHMA	26°40' N	77°21' W	3	3	4	6	4										5	4	3	5	5			
GRAND TURK	1b	DGRAND	21°28' N	70°09' W			2	6	4									5	4			3	6			
BERMUDA (1 & 2)	2	BMUDA	32°21' N	64°40' W	5	5	5	2											4	4	4	4				
ATLANTIC SHIP	3	ASHIP	28°00' N	40°00' W	4	6	4										4	4	4	5	5					
GRAND CANARY	4	GRCAN	27°43' N	15°36' W	5	4										4	4	4	4	5						
KANO, NIGERIA	5	KANOO	11°34' N	8°16' E	5	6								6	2					6	4					
ZANZIBAR	6	ZNBAR	7°19' S	39°19' E	8	7					5*	6*							1	7	5					
IND OCEAN SHIP	7	ISHIP	28°24' S	73°42' E	8	8	7	8	7	3									7	9	8	8	8	8		
MUCHEA, AUSTRALIA	8	MUCHA	31°36' S	115°55' E	8	9	7											8	9	8	8	6				
WOOMERA, AUSTRALIA	9	WOMER	31°12' S	137°06' E	8	7											8	8	9	9	7					
CANTON, ISL.	11	CNTON	2°47' S	171°41' E	6	4							7	6						7						
KAUAI, HAWAII	12	KAUII	22°09' N	159°38' W		3	4			4	6	2									5	4				
POINT ARGUELLO, CAL.	13	ARFPS	34°35' N	120°25' W		4	5	5	3												2	4	4	4		
GUAYMAS, MEXICO	14	GAYMA	28°00' N	110°50' W	4	4	4	6	4											3	5	4	5	5	1	
W.S.M.R., N. MEX.	15	WSFPS	32°22' N	106°23' W	3	5	5	5													4	4	5	4		
CORPUS CHRISTI, TEX.	16	CCRIS	27°40' N	97°46' W	4	3	5	6												5	4	4	5	5		
EGLIN, FLA.	17	EGLIN	30°27' N	86°48' W	5	5	6	3												4	4	5	5			
					[------->		20	-------		7	11	8	7	12	2	4	16	[------			----->	20	-------	-------]		

* To nearest Minute

* From Computed data (GSFC) 31 Mar 61

MERCURY - 100/260 NM - 18 ORBITS - 33° INCLINATION PERIOD [illegible] MINUTES

TIME OVER STATIONS*

Figure 5B

STATION	NO.	CODE	STATION LATITUDE	LOCATION LONGITUDE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
SANTIAGO, CHILE	MT	SNTAGO	33° 9'S	70°40'W							5	8	9	8	7											7
LIMA, PERU	MT	LIMAPU	11°47'S	77°35'W						6	7	5				5	7								7	7
QUITO, ECUADOR	MT	QUITOE	0°37'S	78°47'W						8	4						6	2						5	7	
JOHANNESBURG, S.A.	MT	JOBURG	26° 2'S	28°14'E		4	9	8	7	8	7										6	8	8	7		
ASCENSION ISLAND	AMR	ASCEN					5	8					4	7								7	7			
ANTOFAGASTA, CHILE	MT	AGASTA	23°37'S	70°16'W						2	8	8	7	7	8	6									6	7
JUAN FERNANDEZ ISF.		FRDEZ										8	8	9	8	5										
SAN SALVADOR	AMR	SADOR			3	1	4	6	4									2	4	3	5	5				
ST. VINCENTS ILE.		SVINC				5	6									5	1				6	4				
BLOSSOM POINT, MD.	MT		38°26'N	77°05'W																						
FORT MYERS, FLA.	MT		27°30'N	80° 6'W																						
ANTIGUA ISLAND	MT		17° 9'N	61°47'W																						
SAN DIEGO, CAL.	MT		32°35'N	116°59'W																						
E. GRAND FORKS, MINN	MT		47°42'N	92°00'W																						
ST. JOHNS, NFDLD.	MT		47°30'N	52°36'W																						
FAIRBANKS, ALASKA	MT		44°57'N	147°42'W																						
SO. ENGLAND	MT		51°30'N	0°E/W																						
WOOMERA, AUSTRALIA	MT		30° 6'S	136°47'E																						

* To nearest minute

* From data computed (GSFC) 31 Mar 61

MERCURY - 100/260 NM - 18 ORBITS - 33° INCLINATION

TIME OVER STATION/ORBIT

Figure 6

ORBIT NUMBERS 1 - 5 > 20 MINUTES	6	7	8	9	10	11	12	13	14 - 20 > 20 MINUTES
MERCURY NET	7	11	8	7	12	2	4	16	
MERCURY NET PLUS SANTIAGO, CHILE	7	16	16	16	20	9	4	16	
MERCURY NET PLUS JAUN FERNANDEZ ILE.	7	11	16	15	21	10	9	10	SHIP
MERCURY NET PLUS ANTOFAGASTA, CHILE	9	19	16	14	19	10	10	16	
MERCURY NET PLUS ANTOFAGASTA, CHILE & QUITO, ECUADOR	17	23	16	14	19	10	10	22	
MERCURY NET PLUS SANTIAGO, CHILE PLUS LIMA, PERU PLUS ASCENSION ISL.	13	23	21	20	27	9	9	23	
PLUS JOHANNESBURG, S. AFRICA PLUS QUITO, ECUADOR JAUN FERNANDEZ ISL.	29	34	29	28	36	17	14	29	

The foregoing is really only a start on the problem and a very detailed study should be made when the spacecraft requirements for orbital coverage and recovery become firm. The orbital recovery problem is discussed further in section 10. As far as coverage, the 18 orbit mission will have the most stringent requirements and the following Apollo orbital missions might be slightly less stringent due to higher altitude orbits.

As far as the ground instrumentation approach, the closeness of the 18 orbit mission implementation date and the investment in certain equipment indicate the retention of the 225MCS band for telemetry, voice and command is mandatory and appears to be a reasonably good frequency band, from a technical sense, for the Earth orbiting missions. It is noted the Convair, GE and STG reports used the 2290-2300 MCS band for the deep space Apollo missions and suggested both frequency bands, i.e. 225 MCS and 2295 MCS, be used in the orbiting missions as essentially alternate systems. This proposal has many merits. It would provide a highly reliable backup communication system. It allows the spacecraft astronaut to change immediately from the communication system at 225 MCS, which for illustration may fail, to the 2295 MCS system without any loss in communication capability. This will give increased confidence to ground and spacecraft personnel and tend to prevent hasty decisions being made, based on a lack of space-Earth communications. Of course one might argue that two separate 225 MCS systems would be slightly more reliable due to redundancy. Although true, the requirements for the elliptical, circumlunar and lunar missions will need the 2295 MCS system as discussed later. On the ground, this will require most of the stations to be equipped for 2295 MCS. This does not appear too bad since the AMR, PMR and WSMR are planning to have capability at this frequency by 1964. A station would require a 20-30 foot parabolic antenna with automatic tracking feed on a steerable mount. A conical scan tracking system would be reasonably economic, but the use of the more expensive monopulse tracking system should be considered, since it may prove useful in other NASA and DOD programs. Each station so equipped would also need a tracking receiver, displays, recorders, collimation gear, and a 2113MCS command transmitter.

The spacecraft should use a slightly directional antenna, probably with no more than 5 db grain for the 2295 MCS system. If the spacecraft is attitude stabilized towards the center of the Earth, no antenna motion is needed. Using moderate power, it should be possible to transmit

television pictures quite easily in real time with high resolution to the 20-30 foot antennas proposed. As far as modulation, it is fairly obvious the PCM/PM system is optimum despite certain inefficiencies. As many of the important communication links should be digitalized as possible, and the GE approach proposes this for all telemetry, command, voice and television. Further study is needed on the voice digitalization proposed by GE. In particular the optimum digital sampling rate, the definition of "high quality" voice and the necessary signal to noise ratios require clarification. One should insure the PCM encoding is as compatible with machine/computer processing as possible, since the flight schedule is so compressed that information feedback may otherwise be impossible. The encoding system should also be as efficient as possible. In this connection,one might consider elimination of word synchronization bits. If a stable enough bit rate and frame synchronization can be obtained, word synchronization can be easily recovered by a prior knowledge of the encoder construction. Since this area is well considered in the referenced studies and is not critical, it will not be mentioned again.

For tracking the orbital missions, the present FPS-16 radars should be modified for increased capability. This modification consists of using a larger (30 foot) antenna, increased receiver sensitivity, an all electronic 5000 mile ambiguity range machine, and greater transmitter power. Improvements in the spacecraft transponder should also be made. An improved FPS-16, as described above, will be in production soon at RCA with a FPQ-6 nomenclature. Although the S band VERLORT System should be retained initially for added coverage and backup reliability, its use in elliptical, circumlunar and lunar missions is limited. It would appear no major modifications, except improvements in the spacecraft transponder, are warranted. Possible interference between this radar and the 2113-2295 MCS system should not be overlooked. The feasibility of completely eliminating the S band radar in the later missions should be considered.

To increase tracking coverage, it appears at least two additional FPQ-6 radars should be added, one at the Canary Island station and at least one either at the Antofagasta, south of Japan or ship installation discussed earlier in this section. It is also recommended that the feasibility of using the proposed 2113 MCS ground command and the 2295 MCS telemetry link as a doppler transponder for orbital missions be investigated. The doppler information could be useful for up-dating the initial orbit and may reduce the requirement for additional radar coverage. With little extra station equipment, it should be possible to determine spacecraft range rate to an accuracy of 2 fps (radially).

The use of a Minitrack beacon has also been proposed. Since the Minitrack 136 MCS interferometer will give only a few direction cosine angles per orbit and since the previously mentioned or proposed systems are adequate, it would not appear the Minitrack beacon is necessary.

Concerning the network diagrams,* the first one is for the 18 orbit mission using an Atlas booster. The intent is clearly evident, and if a site south of Japan is selected over Antofagasta (entitled on the chart as Santiago--a possible alternate), the problem of foreign agreements can possibly be eliminated. It is important to note the computer run* shows less than a two week slack. This network is the only time critical element in the ground instrumentation area. It is felt with sufficient funding in FY 1962, the necessary instrumentation can be made ready in time to meet the scheduled flight date.

The second network is for the Apollo orbital missions using Saturn or Nova boosters. One should note several of the items on the 18 orbit mission network are repeated on the orbital mission network. This is to present a logical complete network. Obviously all such duplicate items will be accomplished on the 18 orbit mission time scale and will not be repeated, except for necessary augmentation or addition. The orbital Apollo network also shows the facilities needed for the parabolic re-entry tasks, spacecraft drop tests and bio-medical recoveries from Agena and Centaur. As shown by the computer run, the ground instrumentation area is not a time critical one for the Apollo orbital missions.

It is necessary to correlate the networks for the 18 orbit and Apollo orbital missions to see the program. The program is one to give a high degree of coverage, not minimal. Due to time and other limitations, it was planned to install a complete Mercury-Apollo site with FPQ-6/FPS-16 radar near the Antofagasta Minitrack site in time for the 18 orbit mission coverage requirements. However an alternate location south of Japan may be more desirable. Secondly, a "third" Mercury ship with telemetry, voice and command would be created. It would be used to increase coverage in the central Pacific and would possibly be near an emergency recovery area such as Midway. If the ship could be placed near an emergency recovery area, some crude tracking capability should also be installed. Additionally most of the existing Mercury stations would be instrumented for the mission, such as installation of PCM equipment, and a telemetry-voice-command capability added to certain NASA stations in South America and Africa and to the AMR station at Ascension Island. For the Apollo mission, it was planned to implement the Midway site or a "fourth" ship which would include a precision tracking capability (FPQ-6/FPS-16). The "third" Mercury ship would be repositioned in the north Central Pacific for the Apollo elliptical, circumlunar and lunar mission coverage.

* All network diagrams and computer runs are compiled in another portion of the report.

5. Elliptical Flight Instrumentation

The requirements and flight profile for the elliptic orbit missions are still not clear. It was assumed one would start with an apogee of 500 miles, then of 50,000 - 80,000 miles, then of about 200,000 miles (in front of Moon) and finally of 260,000 miles (the circumlunar orbit). In the first two cases it was assumed the perigee was at least 150 miles and several orbits are made. The last two cases were assumed to be one orbit missions only and, due to the similarity to a simplified lunar mission, are discussed only briefly in this section.

Considering the 500 mile case first, it appears the stations and approach described in the orbital case are sufficient.

The orbits with apogees of 50,000-80,000 miles and perigees of 150 miles present two problems:

a. Although excellent coverage can be obtained of the apogees, which constitute the major time of the flight, the coverage of perigee may be very poor since they may occur in areas of no coverage and, even where existing coverage exists, the tracking rates will be extremely high. It is felt the spacecraft requirements during the short perigee passes for telemetry, voice and command should be extremely low, if existent at all. Therefore it is not proposed to add any facilities to obtain perigee coverage for these purposes. However, some tracking coverage of perigee would be highly desirable for obtaining the orbital parameters accurately and rapidly. To meet this requirement, it is suggested the orbital parameters be designed so the first few perigees occur within the coverage of existing or proposed Apollo stations with radar tracking. Referring to figure 9, a typical elliptical orbit is shown. The ground station coverage on the figure should be disregarded, and the figure has been shown mainly to illustrate where perigees can occur and the typical ground plot. Such ground plots are deceptive since the spacecraft spends vastly unequal amounts of time per unit length of the ground track.

b. The second problem is the fact the orbital stations do not have sufficient communications capability, at distances beyond several thousand miles. Using logical assumptions for the spacecraft transmitter power and antenna gain, the 225 MCS system will become unsatisfactory at distances of 4000 - 10,000 nautical miles. At such time the astronaut must switch over to the 2295 MCS system. From this point to apogee, the

Figure 9

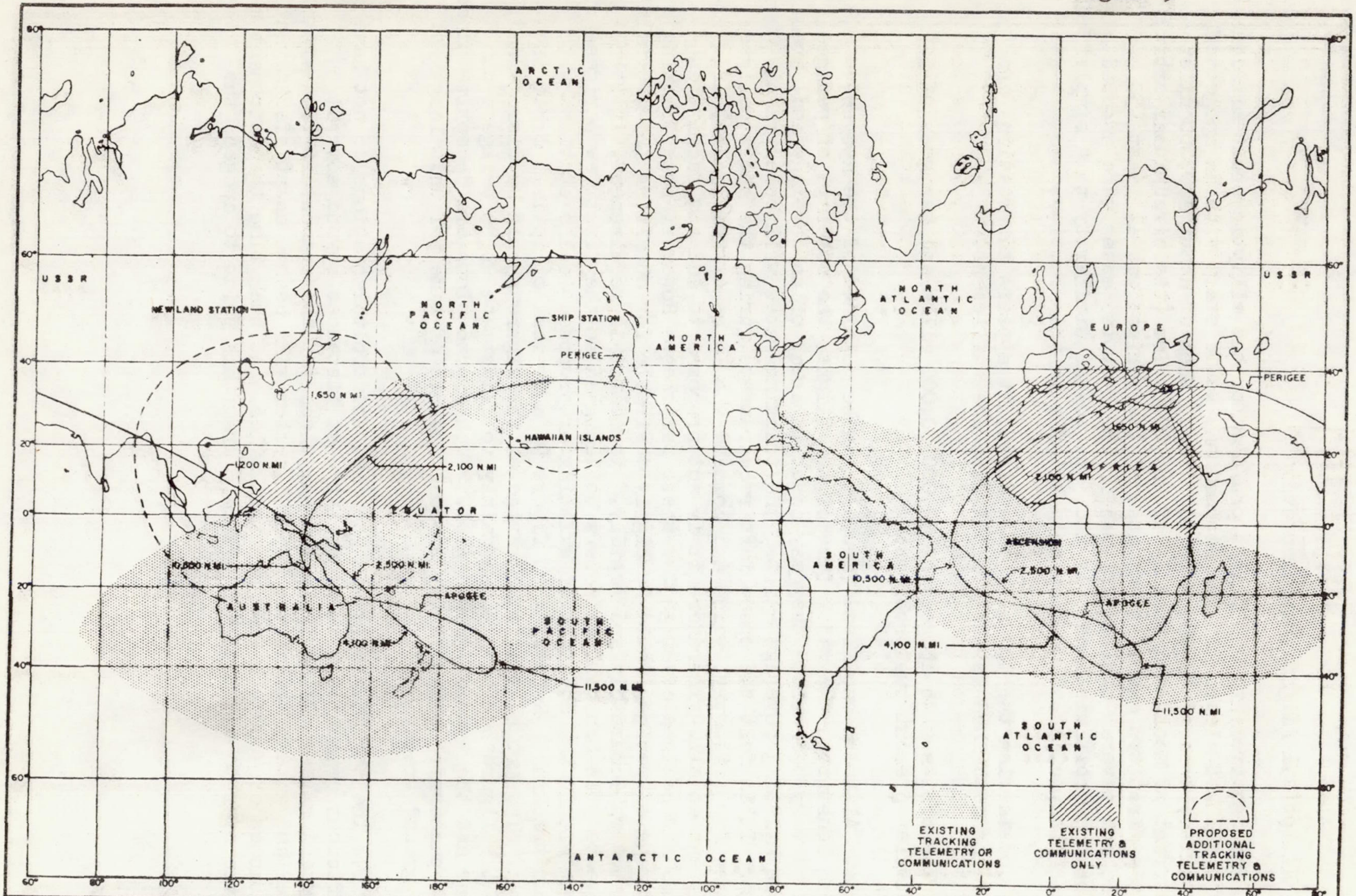


Figure 9

Elliptical earth orbit tracking and communications coverage

communications can be handled in the 50,000-80,000 mission by the proposed 20-30 foot antennas with possible use of the DSIF 85 foot antennas for increased signal margin at apogee. As the astronaut approaches perigee again, it would be possible to switch back to the 225 MCS system. The point of the above discussion is if the 20-30 foot antenna proposal is adopted and placed at most of the stations, there is no need to switch from the 225 MCS to the 2295 MCS and visa versa, i.e. the whole mission could be performed at 2295 MCS.

For the one orbit mission with apogee of about 200,000 miles, the problem is so like the lunar case, the discussion in section 8 seems to cover this mission. The circumlunar mission or the 260,000 mile apogee is interesting from two standpoints. One is the possible perturbations of the orbit by the Moon, if the lunar perigee is too close, will cause a tracking data problem. The accuracy of the tracking data as the spacecraft comes out from behind the Moon's shadow appears to become critical. This should be further investigated. However, the problem is no worse than the lunar take-off tracking problem discussed later and, if the lunar take-off problem is solved, this should present no problem. Also, the circumlunar orbit could be planned with a large lunar perigee to make the Moon's effect small. The second point is that this study, and the studies reviewed, propose no communications with the spacecraft when it is behind the Moon. All data received while behind the Moon could be recorded for later transmission or subsequent physical return to Earth. There is no easy way to circumvent this communications blind spot. Elaborate ways such as a relay-repeater do not seem justified.

6. Guidance Instrumentation

The guidance ground instrumentation is directly related to the ground capabilities for tracking and communication previously discussed. To a large extent, the guidance for abort situations is discussed in section 7.

The following philosophy has been assumed for the spacecraft guidance system. First the spacecraft is assumed to have a complete on-board guidance system. Measurements made from the spacecraft of various heavenly bodies will provide the input to a spacecraft computer controlled by the astronaut. After making measurements and entering these in the spacecraft computer, the astronaut will cause the computer to compute a certain desired maneuver (the bulk of the material being pre-programmed). The computer would perform the calculation and display the results. If the results appear satisfactory, the astronaut will press an "initiate" button, which will generate the proper commands to the various spacecraft systems at the right time.

It is proposed that an Earth based guidance system be used in the Apollo program for certain phases of flight. The Earth based system would be used as a check against the spacecraft system, as a backup in case of computer failure and as a backup due to astronaut inability to make the necessary measurements in a specified time period.

The Earth guidance system proposed would use the ground tracking data as input, essentially making it completely independent of the spacecraft guidance system. From the tracking data and information received from the spacecraft via the telemetry link, such as spacecraft attitude, the Earth guidance system will compute the proper commands for the maneuvers to be described below. The Earth computed commands would be transmitted to the spacecraft where they would be stored and displayed. In normal operation, the astronaut would be able to choose from the two displays which of the two commands (Earth measurement or on-board measurement) he wishes to initiate, if they are different. Additionally, for emergency cases, the Earth command system should be able to force the spacecraft to "initiate" a command, using the Earth guidance data. It is proposed the guidance during various flight phases be:

a. Launch through injection. Pre-programmed all inertial system with no control from Earth or spacecraft except in an abort situation.

b. Midcourse. Midcourse correction is quite difficult. One would like to make the correction right after injection, but until enough

tracking data (spacecraft on-board or ground measurements) is acquired to determine the actual orbit being traveled by the spacecraft, no corrective maneuver can be made. Normally, lunar spacecraft can be given a midcourse correction from Earth guidance about 7-12 hours after injection. However, if the trajectory has a wide deviation from nominal, it may be possible to make a rough correction about 3-5 hours after injection. It is proposed to have the DSIF capable of making such a midcourse guidance correction. If the spacecraft on-board system can make better determinations for the initial correction than the ground system (i.e. in a shorter time), it would perform the maneuver. Subsequent corrections will probably find the two guidance systems about equal in capability.

c. Moon approach. It is proposed the Earth guidance system be capable of making such a maneuver. The use of the lunar transponder (see section 8) would substantially aid the spacecraft and Earth guidance systems. Again the two guidance systems should have about the same capabilities.

d. Moon landing. The accuracy of the Earth based guidance system appears so low compared to the spacecraft system, it is not proposed to have an Earth guidance capability for this maneuver. The spacecraft guidance problem may be eased by the possible TV capability on the lunar transponder mentioned in section 8.

e. Lunar takeoff. This is almost a predetermined guidance problem. The Earth guidance system should have equal capability with the spacecraft system, and it is proposed to have the Earth guidance system able to perform such a maneuver.

f. Lunar-Earth guidance. This is the "inverse" problem of the mid-course guidance problem previously discussed. It is proposed to have the Earth guidance system capable of making this correction, although it may not have an equal capability. The possible reduction in capability of the Earth guidance system in this flight phase as compared with midcourse is due to less accuracy of measurement over the longer baseline distance, the two second transit time lag of signals, and the relatively short tracking time available before the maneuver should be made.

g. Guidance for Earth re-entry. If the spacecraft is to perform vernier corrections prior to re-entry, possibly necessary to hit the proper corridor, some guidance may be needed. Guidance at this point could be useful in placing the spacecraft nearer to a predetermined recovery area. It is proposed the Earth guidance system have the capability of performing this guidance phase. The Earth guidance system should have equal capability with the spacecraft guidance system.

h. Earth re-entry and landing. It is proposed to have no Earth guidance capability as such for these phases of flight. However, it is thought necessary to have some navigational aid type systems on the Earth. As the spacecraft emerges from the re-entry "blackout"conditions (approximately 150,000 ft), the astronaut should determine as soon as possible the proper flight path to the recovery area. This is necessary if the full maneuverability of the spacecraft is to be used. The proper flight path can be determined by the astronaut using the previously mentioned ground navigational aids or by information (voice would possibly be sufficient) from a ground controller, if sufficient ground tracking data after re-entry blackout was avilable. The previous discussion has assumed a direct "parabolic" type re-entry method, and a different Apollo re-entry method might require other types of ground instrumentation. Once the flight path is determined, it was assumed the astronaut would guide the spacecraft to the landing area and land by some means. More information is needed on spacecraft requirements in this area before ground instrumentation can be defined. However, it is probable that whatever navigational aid system is chosen, an all weather capability is necessary.

i. Recovery. Assuming the maneuverability of the spacecraft is reasonable, little instrumentation should be needed to guide the recovery forces to the spacecraft. It would appear the same general type of rescue beacons, such as is currently in use by Project Mercury, would be sufficient.

7. Abort Instrumentation

The ground instrumentation for aborts has been mentioned briefly in several other sections of the report, but has not been well specified. The problem of abort is closely related to the guidance and recovery sections of this report.

The philosophy assumed for the Nova missions, and which applies reasonably well to many of the Saturn missions, is that the spacecraft will have its own reliable propulsion system on board the spacecraft for use in abort situations. As an example, the rocket engine in the spacecraft for take-off from the Moon could conceivably be used for abort propulsion during the injection phase. The purpose of abort propulsion would be to accelerate or de-accelerate the spacecraft into a relatively few, predetermined recovery areas.

It is proposed the abort system function with the same philosophy as the guidance system. This is to have any ground station, with coverage of a critical stage of flight, be able to send a command to the spacecraft to abort the mission. This command is obviously not simple and most contain sufficient guidance information to allow the spacecraft to perform the proper propulsion and maneuvers required for safe return. It is emphasized that the spacecraft should also have a complete on-board capability to abort at any critical portion of flight and return safely. The ground system for abort is a backup and a means to terminate the mission when ground information, possibly not available or recognized on the spacecraft, indicates such action is advisable.

It is proposed the following phases of flight be able to be aborted by ground station command:

a. On pad. This is similar to Mercury where abort could be initiated by the booster abort sensing system, the astronaut or the ground.

b. During and at the termination of any booster stage firing period including injection. Since continuous telemetry, voice and command was proposed for these flight periods, the only problem is how the ground station will know the proper command to abort the spacecraft into a predetermined recovery area. This problem appears solvable but, depending on the number of allowable recovery areas, could be quite complex.

c. Once each orbit for orbital and slightly elliptical missions. As in the above paragraph, there is no unsolvable problem as long as the station can generate or receive from the control center the proper commands. Again the number and location of recovery areas is important. Also the capacity and reliability of the ground communications between stations is a factor, since few stations have metric capabilities and almost none have the needed computer capability. Currently only the Cape Canaveral and Bermuda stations have both tracking and computer capability. If Ascension is used in the Apollo missions, it is possible that planned computer facilities for other programs could be satisfactory. However additional computer facilities could also be required at certain new sites.

d. Flight paths away from the Earth (elliptical or lunar outgoing), lunar landing and outgoing midcourse maneuvers. Assuming the previously mentioned spacecraft propulsion, such aborts from ground stations will be relatively easy. The ease is due to the low number of ground stations needed to cover such flights and the proposed spacecraft ability to land in only a few, pre-determined recovery areas for these specific types of flight profiles.

In practice it is speculated the spacecraft guidance computer would keep a running tally of the best estimate spacecraft position, primarily from on-board measurements. At an abort signal from the spacecraft, astronaut or ground, the spacecraft computer would use this position data plus an abort program containing the available recovery areas to calculate the proper abort propulsion, attitude, etc. It is proposed that the ground stations, using tracking data, continuously compute abort guidance information on the premise of a near instantaneous abort situation. This ground abort information would be continuously transmitted to the spacecraft. Therefore in an abort situation, the astronaut could choose between the abort guidance calculated on board the spacecraft or the ground computed abort guidance. In certain situations, such as astronaut incapability, the ground station command should be able to force the spacecraft to follow the abort initiation and abort guidance being generated on the ground.

8. Lunar Flight Instrumentation

For all the Apollo missions with trajectories having distances greater than about 8000 nautical miles from the Earth (highly elliptical, circumlunar and lunar missions), the general telecommunications and tracking problem can be efficiently handled by the Deep Space Instrumentation Facilities (DSIF). The Convair, General Electric and Space Task Group reports on Apollo use the DSIF for coverage and since these reports contain a detailed description of the ground instrumentation, only selected topics of a more controversial nature will be discussed.

Figure ten shows the coverage from the three DSIF stations at Goldstone, Woomera and Johannesburg for a 5 degree elevation mask. This figure shows complete coverage of the Apollo spacecraft can be achieved when the spacecraft is relatively far from the Earth. The amount of coverage overlap and the elevation angle from the stations vary widely with the change of Moon declination. Slightly better coverage is available for Moon declinations in the range of 10°N to 28°S. It is again noted that coverage will not be obtained when the spacecraft is behind the Moon for circumlunar missions.

In general the handling of the communications by the contractors was good, and only a small number of errors in assumptions and calculations were noted. An Earth track of a typical lunar trajectory is shown in Figure 11. This figure shows the coverage proposed for the beginning and end portion of the lunar flight. Of particular note is the orbit retrograde at the beginning of free space flight over South Africa. This retrograde means the station in Johannesburg could maintain continuous coverage from about one hour after launch to at least eight hours later. Such coverage makes the Johannesburg station, and the reliability of ground communications from it to the United States, of great importance. Figure 11 also shows a possible re-entry trajectory. If this type re-entry track is correct, the use of a possible new land site (northeast of the Philippines or south of Japan) and a ship station (north central Pacific), previously mentioned under the orbital missions, appears optimum. Again the need for rapid specification of the re-entry and recovery phases of Apollo flight becomes evident, since many of the proposed alternate recovery methods would change the location and type of ground instrumentation stations.

One of the problems not covered by any of the studies was failure type communications on the lunar missions. The communication at lunar distances is predicated on use of a reasonably directive antenna.

Figure 10

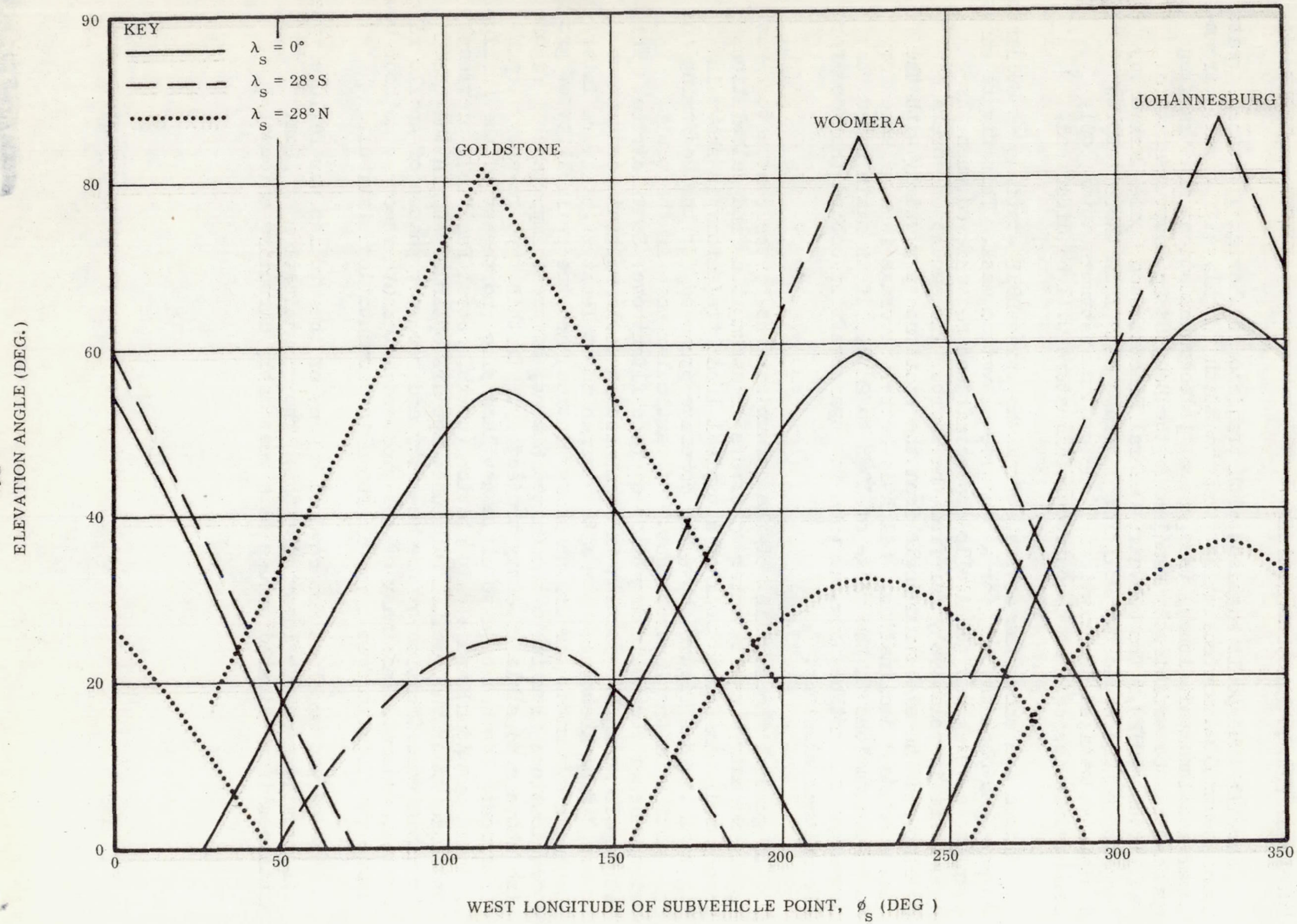


Figure 10 Coverage from DSIF Stations

Figure 11

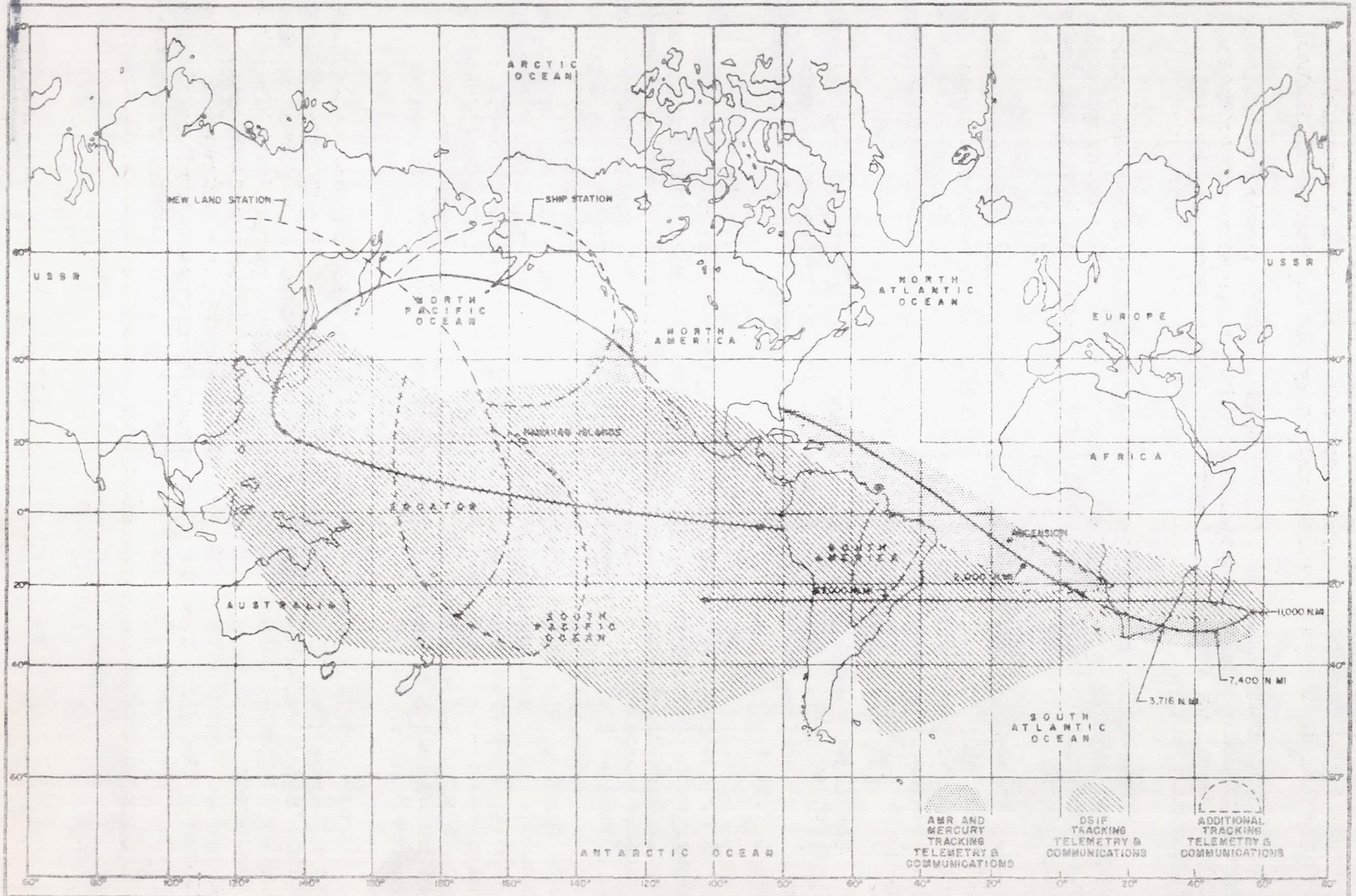


Figure 11

Illustrative lunar flight and return trajectory

CONFIDENTIAL

Assuming that upon lunar landing the directive antenna or the mechanism to point it is damaged, no communications at all will be possible. It is suggested an emergency communication system be created as follows:

a. Spacecraft antenna. Four antennas, each covering about 140 degrees of solid angle be installed. Slot type, skin mounted types would probably be adequate. Fewer than four antennas may be more optimum in practice.

b. Spacecraft transmitter. Two watts output at 2300 MCS, which can be switched to any one of the four antennas. The astronaut would determine which antenna was pointing to the Earth and attach the transmitter to it.

c. Ground antenna. A parabolic aperture about 220 feet in diameter with reasonably high efficiency at 2300 MCS. Such antennas appear necessary for planetary spacecraft requirements. As described below it would be possible to construct these for use in Apollo without changing any current schedules or funding proposals.

The above system would give a bandwidth at least 3000 cps wide with a 10 db S/N ratio. This is adequate for failure telemetry or voice which has been encoded by PCM (quality real time voice should have 20-30 db S/N ratios).

A second problem is transmitting television from the Moon. The Convair study did not attempt this for obvious reasons to be discussed later. However, STG and GE proposed non-real time TV pictures. The GE system proposed would have a capability of about two pictures per minute. It is suggested that real time television could be transmitted from the Moon for reasonably long periods. It would appear the possible requirements for real time television, both technical and political, might be examined. If a requirement exists, real time, high resolution TV could be transmitted from the Moon using PCM picture encoding prior to transmission, only seven watts of spacecraft radiated power (into a four foot diameter spacecraft), and a ground receiving antenna of about 220 foot diameter. Less spacecraft power could be used with increased spacecraft antenna diameters.

It is currently proposed to build a large NASA antenna at Goldstone with a 210-240 foot diameter starting in 1962. It is suggested that this antenna plus a second antenna of this size, located in Italy or South Africa, could be completed before 1967. Using these two antennas and the 210 foot CSIRO antenna in Parkes, Australia, it is possible to achieve <u>nearly</u> continuous lunar coverage. Figure 12 illustrates the coverage of these antennas. The plots look peculiar since the antenna mounts are in azimuth-elevation coordinates, and the map projection is not ideal. The coverage

limit of each antenna describes approximately a great circle on the Earth which on this projection will resemble a sine wave. The points of the arrows on the sine wave show which side of the wave has coverage.

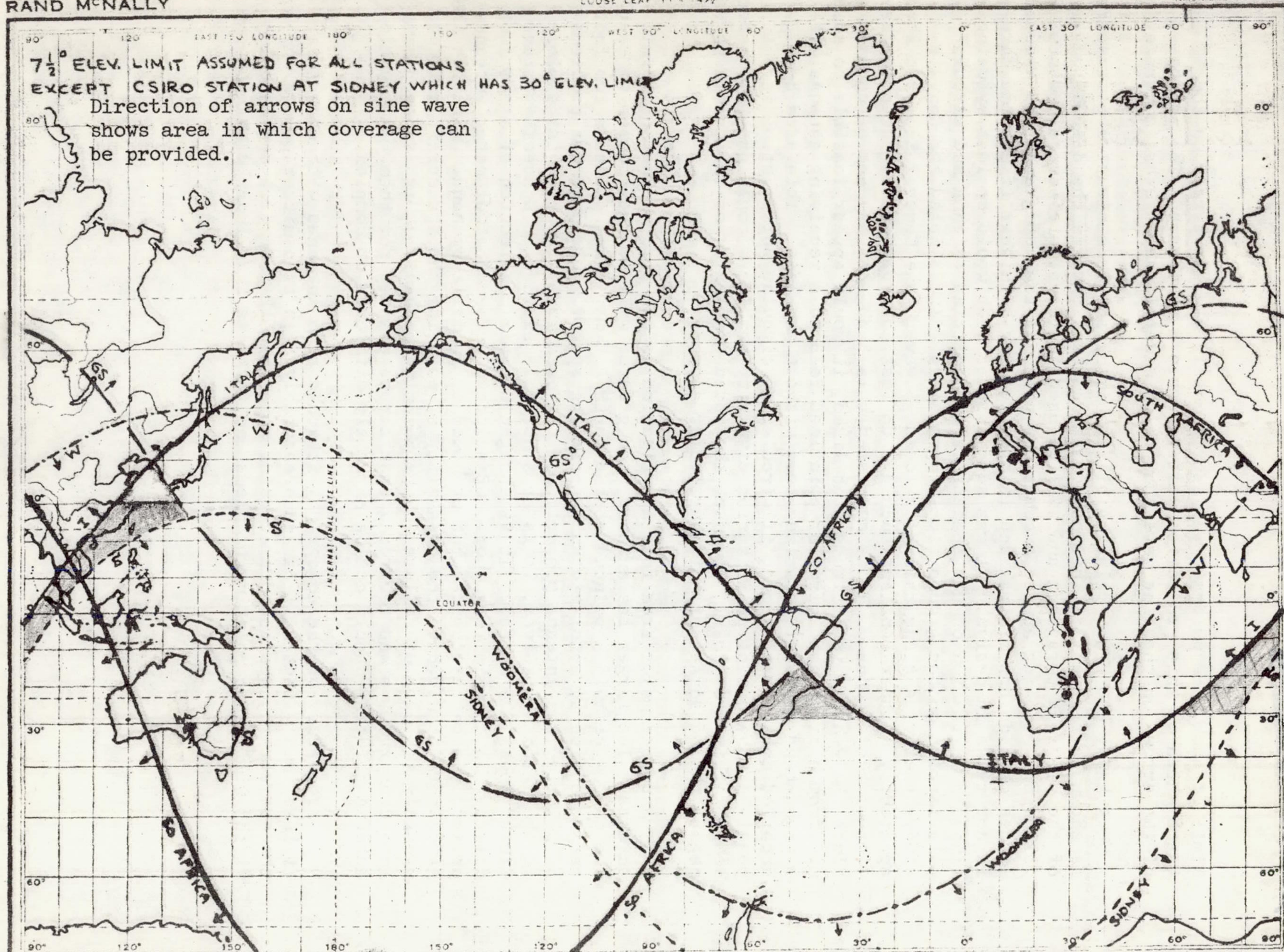
A handy nomograph relating all the important communication parameters is shown in figure 13. This nomograph has been used in the discussion of the previous paragraph and will be used to illustrate several points following. Looking at the assumptions noted on the nomograph, the assumed losses of 6 db are minimal and in practice may be higher if extreme care is not taken in design. It was also assumed 3 db would be lost by using linear polarization on the spacecraft transmitting antenna and circular polarization on the ground receiving antenna. It is noted the Convair study briefly mentions this 3 db loss. However, the General Electric study apparently neither mentions such a 3 db loss nor even states the polarization of the antennas. It is suggested this 3 db loss may not be necessary. Since the vehicle is attitude stabilized, it would appear feasible to transmit from a right-hand circular polarized feed to a receiving antenna with a right-hand circular polarized feed without any loss. This area bears detailed consideration and, if circular to circular polarization is not possible, the use of polarization diversity combiners could possibly reduce some of this 3 db loss. However, the added complexity of the combiners may negate the advantage of this particular approach.

A second major area for investigation is the size of the spacecraft antenna. The larger the antenna, the greater will be the problem to keep the narrow beamwidth pointed at the Earth. Convair has chosen a two foot parabola with an automatic Earth pointing system. Although the problems of pointing the antenna properly and the need for large beamwidths close to the Earth are solved, it is at a horrible expense to spacecraft transmitter power (25 watts). It is thought Convair's selection of a two foot diameter antenna is very poor. GE selected a four foot diameter antenna, obviously a better choice, but proposed to point it by hand. Although the astronauts should have the capability of pointing the spacecraft antenna manually (in case of failure in the pointing mechanism), it is hoped some more constructive and rewarding task can be planned for them. Automatic antenna pointing should not be extremely difficult or complex.

From study of the nomograph, it would seem antennas with diameters of less than 4 feet will cause unreasonably high transmitter powers on the spacecraft, whereas diameters of more than 12 feet (2.5 degree beamwidth) will cause pointing problems and for less than lunar distances

ESTIMATED STATION COVERAGE 200'-250' DIA. ANT. LUNAR RANGES

RAND McNALLY OUTLINE MAP LOOSE LEAF 11 x 14½ Figure 12 WORLD AMERICAS CENTERED

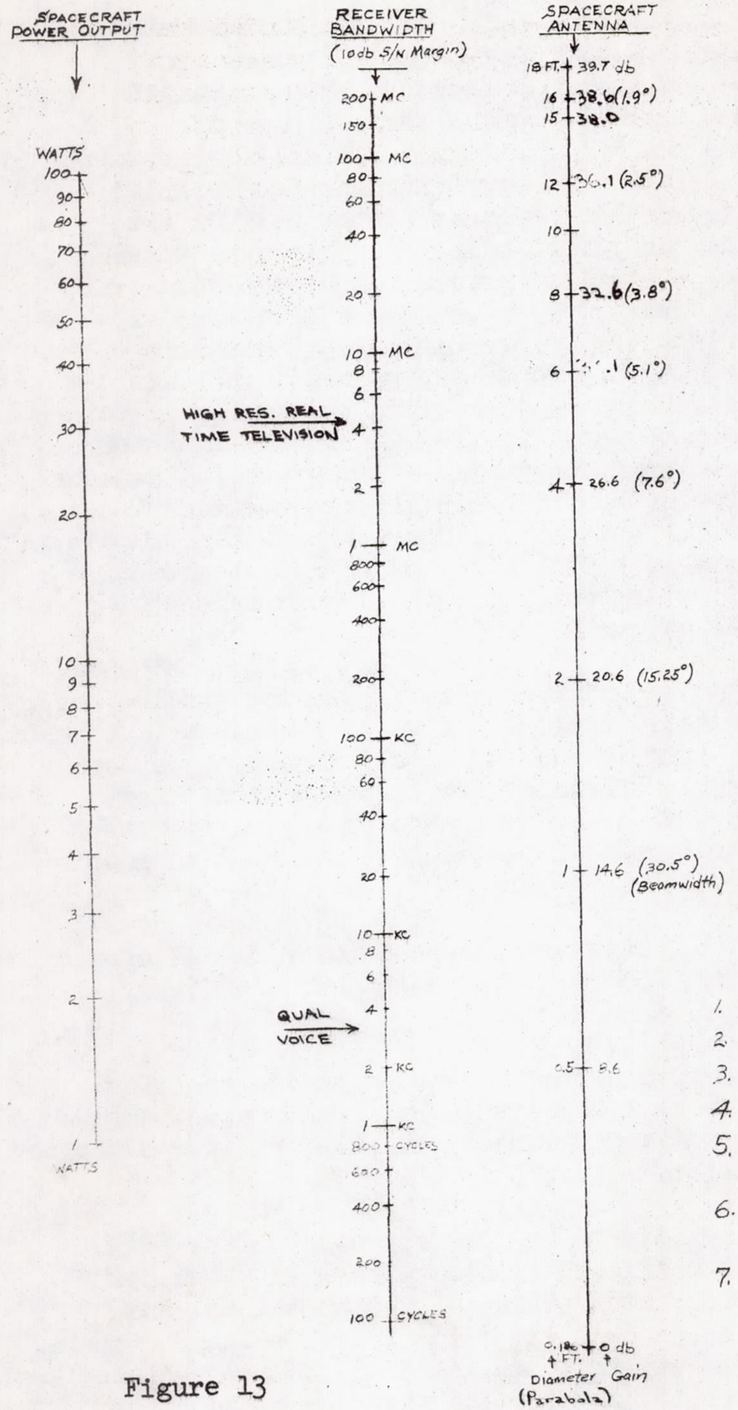


OC 901

Shaded areas show lunar coverage possibly lost by using Italy and CSIRO station at Sidney in lieu of Woomera and South Africa. Full coverage is area from 28°N to 28°S Declination PSG 6-6-61

APOLLO LUNAR COMMUNICATIONS

Figure 13



NOTES

1. Frequency - 2295 MCS
2. Moon - Earth Loss - 212 db
3. Misc. Losses Assumed - 6 db
4. Polarization Losses Assumed - 3 db
5. Loss for Carrier Power for Tracking Assumed - 2 db
6. 300°K Total Receiving System Temperature Assumed
7. 85 Foot Parabolic Antenna With 53 db Gain

Figure 13

the beam will not completely cover the Earth. It is concluded the optimum diameter would be between 4 and 12 feet for the spacecraft antenna and the precise diameters can only be fixed after detailed study. However, it is obvious that one really desires a variable gain and, therefore, a variable beamwidth antenna. Ideally the antenna would have about 3 db gain close to the Earth and increase in gain gradually until about 35 db is reached at lunar distances. On the return trip the antenna would lose gain similarly. This type antenna is not fantasy. One could use a static phased array as the spacecraft antenna on a steerable mount. The array would have a gain of 35 db with all elements connected. However, one could make it possible to disconnect elements from the array to reduce the gain and increase the beamwidth as desired. An array using beam steering by phasing is not recommended. However, arrays have many drawbacks, and such a system may not be desirable. An alternate would be to use a two parabola antenna system, say a one foot diameter antenna for the closer communication distances and a six foot diameter antenna for the lunar distances. To save space and mounting, it may be possible to design a Cassegrain antenna system with a low f/D ratio, where the Cassegrain reflector serves as the smaller antenna as well.

The next problem is one of ground tracking. Again the studies cover this area fairly well and suggest essentially a range and range rate scheme. It is noted the proposed DSIF ranging system is only in prototype form and no models of the spacecraft transponder are in production. For optimization and compatibility, it is proposed the work pace on these items be increased immediately. It is hoped to have flight test models ready by 1963.

Another suggestion which may improve guidance, tracking and communication is the "lunar transponder". It is proposed to land a Surveyor weight payload on the Moon which would be used for:

a. Marking the landing spot for subsequent Apollo vehicles. The Apollo vehicles would "home" in on the transponder. The transponder would contain a command receiver, so it would radiate only during needed periods and thereby increase the transponder life.

b. A communication relay. During the approach to the Moon, landing and takeoff, it may be difficult to communicate with the Earth due to spacecraft maneuvers, inability to rapidly point the antenna, flame antenuation, etc. For these conditions and possible lunar mishaps, it may be easier for the astronauts to communicate via the omni-directional spacecraft antenna to the lunar transponder and thence via the lunar transponder to Earth.

c. The spacecraft will probably require an altimeter type instrument for the lunar landing maneuvers. Use of the lunar transponder as an altimeter transponder should give greatly decreased power requirements in the spacecraft and increased accuracy, when compared to a radar altimeter working on reflection. To further decrease spacecraft weight, it might be possible to use the DSIF ranging transponder in the spacecraft (for tracking from the Earth) also as the altimeter itself. However, further investigation is needed to see if this is feasible. Lastly, if such a scheme was used, the DSIF should be able to accurately read from the Earth the spacecraft position above the lunar surface via the lunar transponder.

d. It is suggested this lunar transponder might have a capability to give angle information to the incoming spacecraft as well as range and range rate data. The mechanization of this is not clear unless complex systems are considered. JPL is investigating schemes such as used in airport navigation beacons. However, one method is to have two orthogonal fan beams at different radio frequencies scan from horizon to horizon (in elevation) at a precise known rate.

e. It is suggested in the final landing phase on the Moon, it might be helpful for the astronaut to watch himself land. It would be quite possible for the lunar transponder to have a wide angle television camera looking upwards. On command from the spacecraft, the lunar transponder would start taking TV pictures and transmitting them in real time via low gain antenna to the spacecraft which is, hopefully, only a few thousand feet at most, above the lunar transponder. Since this phase of flight (i.e. lunar landing) should take less than three minutes and the transmission distance is short, this suggestion should not unduly tax the power supply capabilities of the lunar transponder. It may be possible to monitor the television pictures on the Earth via the lunar transponder's high gain antenna, especially if the 220 foot antenna proposal is adopted.

It is felt such a transponder could be built and prototype models landed on the Moon for experimentation purposes by late 1965.

Lastly the subject of the increased Surveyor program is important. It is felt the present DSIF is overloaded as far as 85 foot antennas are concerned due to the following (in order of importance):

a. Scheduling. Starting in 1964, reasonably large amounts of data will be lost due to conflicts between Ranger and Surveyor. It must be realized that maintenance, calibration, equipment installation, etc.

also take considerable time, although much of this can be placed on a non-conflicting basis. Since two spacecrafts can conceivably be on the Moon, the antenna beamwidth of 0.4 degrees can in some situations cause significant signal degradation, since the lunar disc is about 0.5 degrees. Note that a 0.4 degree beamwidth means the signal is degraded 3 db at the limits of the beam. If a lunar orbiter does not achieve a very close orbit, it will be impossible to constantly keep it and another spacecraft on the lunar surface in simultaneous view with such an antenna beamwidth and only one antenna. Also there are critical time periods, such as the Earth-Moon flight, where the complete DSIF network could be tied up for operational reasons about five days on a particular spacecraft. Lastly it had been hoped to use the DSIF occasionally on other programs.

b. R&D. Due to the increase in the Ranger and Surveyor programs, the JPL R&D activities in telecommunications at Goldstone will be reduced seriously, if not halted, by the end of this summer. These R&D activities currently use the two 85 foot antennas which have had a low operational load in the past. JPL R&D activities include original work in components (masers, parametric, propagation, etc.), antennas (large antenna system, servos, structural resonances, noise temperatures, feeds, etc.) and systems (Venus and astronomical observations, the precision ranging equipment, advanced GSDS equipment, high power transmitters, automatic acquisition, etc.). At the current time, no other NASA laboratory has any comparable program and such work is felt vital to future NASA progress.

c. Flexibility. The antennas in use were designed in 1953 and fabricated in 1958. Although completely adequate for current missions, it would be desirable to incorporate several state-of-art antenna improvements into the DSIF. It would be desirable to increase tracking speed, reduce antenna temperatures and feed handling/changing problems (Cassegrain configuration) and improve surface accuracies. With two antennas at a site it will be easier to perform such modifications, to handle more missions, to switch coverage between two missions and to use one antenna as an emergency back-up when a critical mission like Apollo is in flight.

Therefore, it is proposed to add three improved 85 foot antennas with the necessary associated electronics and operational facilities to the DSIF. Two antennas would be started immediately, one for Goldstone to allow R&D to continue and the second for Woomera. The third antenna would be started a year later for location in either South Africa or Italy and could be just operational in 1964. It is felt the additional data return from the spacecraft will be well worth the relatively low cost of these antenna stations.

- c -

The increase in Ranger firings has also caused a minor problem in changing the DSIF frequency from 960 MCS to 2295 MCS, previously scheduled for January 1963. JPL is currently investigating the problem which seems solvable with a possible six month conversion delay.

Referring to the network chart and computer run for the "Apollo, Elliptical, Circumlunar and Lunar Missions", the above discussion is graphically depicted. It is noted the large slack times indicated by the computer show that this network is not time critical.

9. Re-entry Instrumentation

It is proposed to have no ground instrumentation for the re-entry portion of flight. The re-entry portion of Apollo spacecraft flight is defined in this study as starting at approximately 300,000 feet and ending at 150,000 feet. During the re-entry period, there will be no communications between spacecraft and ground or visa versa. This is due to the ionized plasma sheath which will surround the spacecraft during this portion of flight. At 2295 MCS, the blackout should be less than 5 minutes and last from about 300,000 feet to 175,000 feet. Data generated during this period of flight could be recorded on the spacecraft for subsequent physical recovery or with a little effort transmitted to a special ground station in the recovery area. It is felt the problem of communicating during this re-entry period could be solved, but at a high cost of payload weight, power and complexity. Such solutions did not seem particularly desirable.

10. Recovery Area Instrumentation

The requirements for recovery are very important to the ground instrumentation problem and were mentioned as a determining critical factor in several of the other sections. Since these requirements are not yet firm, many portions of this study could not be well defined. It is very important to the planning of ground instrumentation that these recovery requirements be specified as soon as possible.

The first important item is to specify if the spacecraft will be maneuverable after re-entry. This study made such an assumption. However the term "maneuverability" must be defined. If the spacecraft is maneuverable, it is important to find its range, its ability to land on water or ground or both, and similar limitations. If the spacecraft is not maneuverable, it will be necessary to provide instrumentation with sufficient tracking capability to acquire and accurately enough track to direct the recovery forces. On the other hand, a maneuverable spacecraft would require instrumentation consisting of some ground navigational aid in the recovery area, such as TACAN, so the astronaut can determine where the landing field is located after re-entry. A combination of the two above approaches may be needed for semi-maneuverable spacecraft or in case of failure of the maneuverable spacecraft. It was assumed an all weather recovery instrumentation system was needed in either case. If water recovery is used, the use of ships is indicated and is discussed further in section 11.

The next important item is the number of recovery areas and the size of each area required. Recovery areas for aborts at various stages of a mission as well as mission completion must also be specified. Proposals on Apollo recovery have ranged from one to three separate recovery areas of various dimensions. On the 18 orbit mission, it has been rumored the spacecraft should have the capability of being brought down in an emergency on any orbit. Such a requirement would create the need for emergency recovery areas beyond the present Mercury requirements. If this requirement is valid, the number of these recovery areas and the necessary recovery instrumentation for the 18 orbit mission should be specified as soon as possible. Of course not only is the number of recovery areas important, but their location and size is too.

The same unknowns exist, but to a less important extent, on the recovery areas for the bio-medical tests.

- c -

11. Shipboard Instrumentation

Shipboard electronic installations can currently be used to meet certain tracking and data acquisition requirements. Further developments in the future are anticipated to increase the number of these requirements which can be met by shipboard installations. Such shipboard installations can replace ground instrumentation sites for many current and projected NASA missions. Even with these future developments, it appears certain tracking and data acquisition requirements cannot be met technically by shipboard installations and, if the technical complexities are ever overcome, the costs would be prohibitive. Therefore, a number of ground instrumentation sites, located as dictated by the technical requirements of the mission, are and will be necessary for the NASA spaceflight program. The main advantages and disadvantages of using ships for various NASA missions are outlined below:

a. In general, the need for obtaining a site in a foreign country can be avoided (however paragraph d 2 should be noted).

b. The station can be easily moved. This is particularly useful for injection or re-entry coverage, where the injection or re-entry points for various missions occur in different areas in the world. It is also useful for coverage of those missions whose trajectories will change in follow-on programs and for interim trajectories such as sounding rockets or tests of some booster vehicles. In these type missions, moderate accuracy tracking can easily be obtained from ships. Since the above trajectories are usually close to the Earth, data acquisition from moderate gain antennas on ships will generally satisfy the requirements.

The major disadvantages are:

a. Shipboard electronic installations are more expensive and difficult than land installations. Equipment must be specially designed for the environment (humidity, salt, vibration, etc.), electrical interference, allowable packaging size, and maintenance.

b. Operating costs of a ship are very expensive, especially when maintenance, overhaul and support costs are included.

c. Ships can stay on station only a limited amount of time. For long-term missions such as scientific satellites or unmanned lunar and planetary spacecraft, this might require two ships for every one station to obtain the desired period of coverage.

d. Precise tracking from ships is currently very difficult. Obviously, long baseline tracking systems cannot be used. This eliminates use of systems like MISTRAM, AZUSA, CYCLOPS, MINITRACK,etc. However, precision radars of the FPS-16 type can be mounted on ships and used without excessive degredation. This requires an elaborate and expensive system to eliminate the roll of the ship (stable tables, servo platform, etc.). In the future, a tracking system which uses only range and range rate measurements can probably be placed on a ship without some of the above complexities; however, the mechanization of such systems usually require simultaneous coverage of the trajectory at portions where high accuracy is desired, such as vehicle thrust periods, from several stations. Essentially, that is how the AMR RADOP system gets its stated measurement accuracies.

This means several ships are required to cover one specific portion of a trajectory, increasing tracking costs substantially. Also, the distances between the ships and the ship position on the geoid must be known very precisely. This is because any tracking problem is directly related to survey. This is equivalent to knowing the exact position of the ship or inter-ship distances on the Earth's surface at the time the measurements are made. Except in a few small areas of the world, this problem is extremely serious. There are several proposed solutions:

(1) Extend coverage of various navigational aids to a world-wide basis. Notwithstanding the high expense of such a proposal, the currently achievable accuracy still would probably leave something to be desired.

(2) Place the ship near a land mass or sheltered port and survey to a known tie-in. This appears to be the best solution, provided a land area is available near the spot dictated by the trajectory with suitable survey monuments. If it is a foreign port or if the ship anchors within territorial waters, it is possible some foreign agreements would still have to be made.

(3) Use the proposed TRANSIT system for locating a ship. This proposal has great merits, based on the claims of APL for the operational TRANSIT system. However, the operational system is considerably in the future and its ultimate usefulness difficult to assess.

e. Communications from ships cannot always make full use of existing landlines and available military or commercial facilities.

f. Data acquisition and tracking requiring large aperture (paraboloid diameters of 85-210 feet) antennas cannot be well performed from a ship at space probe frequencies. Aperture blockage by the ship superstructure, maintenance, achievement of pointing accuracy, and ability to keep on station for long time periods are some of the problem areas. As an illustration, the antenna reflector (85 foot diameter, 2300 Mcs) must be stabilized on the ship to better than 0.01 degrees absolutely. Without considering wind loadings, the weight of the current 85 foot reflectors runs about 440,000 pounds.

As discussed in previous sections, the Apollo missions can use ships for ground instrumentation platforms for the following missions:

a. Telemetry, voice and command coverage for the orbital missions and the beginning and end of the trajectories for the elliptical, circumlunar and lunar missions. Currently there are two such ships and it is proposed to add two more.

b. Tracking coverage plus telemetry, voice and command coverage for the staging,injection and recovery phases of all missions. For the staging and injection phases, the quality of tracking for vehicle development must be high and will prove to be a major problem in contrast to the medium accuracy tracking required for the spacecraft or down range acquisition. Recovery area tracking will have low accuracy requirements. It is possible the high accuracy requirements can be satisfied by the AMR proposed RADOP system. If higher accuracy is required, an inverse DORA system, proposed by MSFC, might be needed. Both inverse DORA and RADOP require simultaneous observation of the portion of the trajectory being measured from several different locations. Depending on the Nova trajectory, two or three ships could be required for each critical staging. However, the final accuracy of either system will probably be negated in part by survey type errors. It was estimated at least four "tracking" ships were required. One ship was allocated to a main recovery area, the second to an alternate recovery area, the third to parking orbit insertion and the fourth to final injection. If the idea of a two "slot" launch mentioned in section two is used, two additional ships are needed. For this study it was assumed sufficient DOD tracking ships (at least two) with proper instrumentation would be made available so NASA would need to fund only two. The validity of this assumption is questionable, especially since DOD ships may be heavily committed on other important programs.

c. The cost of a ship varies widely on the type of instrumentation installed, especially the tracking system. Fund estimates were based on

a two FPQ-6 type radar system for such "tracking" ships. If an inverse DORA system were used instead, the cost of the ship would be half but, as previously pointed out, at least two ships would be needed.

- C -

12. Ground Communications

It is obvious the present Mercury communication system must be augmented for the Apollo mission. Primarily the problem will be to increase capacity and reliability. The new stations proposed, the added shipborne stations and the new recovery area(s) must also be tied into the system.

A very preliminary look at the above Apollo problem indicates the augmentation of the communications can follow the pattern established for Mercury. Namely this is to rely heavily on leased commercial and existing military-civil facilities. Of course the communications terminals, both transmitting and receiving, are included in the proposed funding of the new Apollo stations, including the ships. However, no long haul facilities were budgeted. Lease costs of such facilities were considered operating costs.

It appears the only areas which may require extensive non-terminal communication facilities are remote recovery areas in the Pacific Ocean. Since the requirements for recovery and the location of such areas are not firm, no detailed investigation could be made.

If the proposal for ground instrumentation backup of spacecraft guidance is used (see section 6), more data of a "near real time" nature must be passed in a reliable manner. It is felt this requirement plus the requirements due to volume of information transfer can be met using augmented leased commercial and military facilities. However, it would appear profitable to investigate the use at certain key sites of small computers and/or data processing equipment to reduce the quantity of raw material prior to transmission.

13. Control Center

Study of the control center problem indicated two important conclusions:

a. If a central control center is established, its geographic location, within reasonable constraints caused by the following conclusion, is not too important.

b. A centralized control center is needed which is the terminus for all communications, has the complete computation capability and can actually direct the Apollo mission.

Further study made it appear that actually a single central control center and four sub-centers may be desired. As mentioned above the central control center would be the communication terminal, handle all computation, data, display, command and processing. Although complete operational control would be vested in the central control center, this center could delegate responsibility for control of certain operations to a sub-center. The sub-centers could be:

1. Launch Operations. This could be an augmentation of the present Mercury control center at Cape Canaveral.

2. Orbital Operations. This could be an augmentation of the present Goddard control center at Greenbelt.

3. Lunar Operations. This could be an augmentation of the present JPL control center at Goldstone or Pasadena.

4. Recovery Operations. Since recovery areas and requirements are not firm, a location cannot be suggested. In practice this sub-center may require sub-sub centers.

The centralized control center, after delegating responsibility for an operation to a sub-center, should have the capability of performing back-up type computations. Also, it would appear economic if the centralized control center could have sufficient computational capacity to process all Apollo information including the telemetry records from the ground instrumentation stations, etc. It is noted there is no reason why the central control center could not be co-located with one of the proposed sub-centers.

APOLLO PROGRAM
SPACECRAFT GROUND SUPPORT FACILITIES
(Excluding Ground Support Instrumentation)

Manned Space Flight Center

The lunar landing mission will involve a technological effort as broad and complex as the United States has ever undertaken, and will require the coordination of a widespread national effort of industrial organizations and government agencies. In proposing a Manned Space Flight Center, it is assumed: (a) the Manned Space Flight Center will serve as the command center for all Apollo program activity; (b) management of this program will require far greater numbers of personnel than now exist in the Space Task Group; (c) that the buildings at Langley AFB, Virginia, presently occupied by the Space Task Group are unsatisfactory, and are unsuitable for improvement and expansion.

The proposed Center consists of four integrated facilities:

1. Office and Project Management Facility

2. Equipment Evaluation Laboratory and Support Services Facility

3. Flight Operations Facility

4. Environmental Test Laboratory

The Office and Project Management Facility is planned to house 1300 persons and will include a library, a cafeteria, an auditorium, a computing and data reduction facility, as well as drafting rooms, engineering offices and executive offices. The Equipment Evaluation Laboratory and Support Services Facility will provide offices and working spaces for 700 persons involved in the test and evaluation of spacecraft structures, mechanical systems, electronic systems, instrumentation, control systems, communication systems and spacecraft crew equipment. The Flight Operations Facility is planned to house the flight operations simulation and training activities, and will accommodate about 280 STG and contractor personnel. The Environmental Test Laboratory is required for simulating a space environment for equipment design and evaluation, mission planning, and crew training. This facility will provide for 165 operating and test personnel.

The entire Center is required as soon as possible; construction of the Office and Project Management Facility must get underway immediately to efficiently centralize the many management functions which must be performed in this complex program. Also, go-ahead is required immediately on the Environmental Test Laboratory in order to have it operational early in the

development program, because of the special construction to be employed for the provision of a 100 foot diameter spherical vacuum chamber.

Preflight Operations Facilities

The build-up of spacecraft preparation activity which will result as the Mercury project speeds up and as Apollo spacecraft become available for flight test, will require considerable expansion of facilities in the Hangar S area at Cape Canaveral. The numbers of spacecraft receiving check-out at the same time and the increased size and complexity of the Apollo spacecraft and associated propulsion systems requires construction of an additional warehouse, a new spacecraft assembly building, offices, a pyrotechnic loading facility, a specialized test building as well as associated roads and parking areas.

Spacecraft Propulsion Check-out Facility

Integrally related to the preparation and check-out of the Apollo spacecraft, the onboard propulsion systems which will provide a mid-course guidance capability, will land the spacecraft on the lunar surface and will return the spacecraft to the earth, must similarly be extensively checked out, and at the same time as the spacecraft. No facilities are available for this purpose and planning must commence very shortly, to provide this capability at the launch site.

SPACE SCIENCE
GROUND SUPPORT FACILITIES
(Excluding Ground Support Instrumentation)

The space science flight program has been reviewed to determine the additional facilities that will be needed directly in support of the recommended additional effort. It is believed that no major additional facilities are needed to support the Scientific Satellite and Sounding Rocket Programs since this effort is an expansion of the current program and the increased effort will largely be handled by contractors. The Lunar and Planetary Programs, however, will require additional facilities to maintain the recommended schedule without jeopardizing spacecraft reliability.

Review of the facilities requirements for the recommended program has indicated that the existing and currently-planned JPL engineering, laboratory, and spacecraft assembly facilities are adequate to handle the portions of the program which are expected to be performed in-house, the Ranger project (including the follow-ons) and the Mariner project. Likewise it seems safe to assume that the contractor selected to handle the Prospector project will have adequate engineering, laboratory and assembly facilities, as does Hughes Aircraft, the Surveyor contractor.

On this basis, only major environmental facilities and launch site spacecraft checkout facilities need be considered, since the launch vehicle facilities, and the Deep Space Instrumentation Facility are being considered elsewhere.

The additional facilities requirements are listed below by the fiscal years in which funding will be required. Only additional facilities have been considered since inclusion of a major facility inventory in this report does not seem logical.

<u>FY 62</u>

1. A 30'x40' Space Simulator to be operational in FY 63.

A single 30'x40' space simulator, capable of pressures as low as 10^{-6} millimeters of mercury, and equipped with cold walls and solar radiation simulation is currently under construction. This simulator will not be available for acceptance testing of Surveyor spacecraft in FY 63 due to the heavy loading from additional Rangers and developmental work on the Mariner interplanetary craft for FY 64. An additional

30'x40' space simulator is, therefore, needed in the Los Angeles area, not necessarily at JPL.

2. Two 10'x20' space simulators to be operational in FY 63.

One 10'x20' space simulator is to be operational at JPL in the second quarter of CY 1963. This chamber is actually needed in early FY 62, for the planetary program. The FY 63 availability is the result of current funding limitations, rather than construction time. Two additional simulators of the same type are recommended to support the Ranger follow-on and Surveyor programs. One of the additional chambers should be at JPL and the other should be in the Los Angeles area available to Hughes Aircraft.

The work load on the 10'x20' space simulators is expected to be quite heavy since these units are well suited to both acceptance testing of complete spacecraft of small sizes, and to long-time developmental testing of large spacecraft subsystems or experiments. It is believed desirable that all spacecraft system contractors should have 10'x20' space simulators in the next few years.

3. A large high frequency shaker to be available in FY 62.

A large high frequency shaker (15 - 1500 cps, 28,000 lbs. force) is currently being procured at JPL for dynamic studies and spacecraft acceptance tests. A similar unit should be available for Surveyor work during FY 62. These large shakers are needed for both developmental and acceptance testing of complete spacecraft, and are also suitable for assembly testing.

4. A large low frequency shaker.

A large low frequency shaker (½ - 50 cps, 25,000 lbs. force) is being procured for evaluation of the dynamic characteristics of spacecraft structure. A similar unit should be available for Surveyor work.

5. Two acoustic test chambers.

Two acoustic test chambers, of sufficient size to test complete spacecraft and structural assemblies such as solar panels are needed to support the Ranger and Surveyor programs. These chambers should be capable of operating at sound pressure levels of about 160 db.

6. An additional spacecraft checkout facility at AMR.

At present one spacecraft checkout bay has been provided in the addition to Hangar AE for Ranger operations and requirements have been

submitted for two checkout bays (JPL Spec. 30225) to support the Mariner double firings. Two such facilities are recommended to handle the high density of firings in FY 62 and FY 64. This requirement could conceivably be met by modification of Hangar AE to include four bays.

FY 63

Although the recommended program will require no facilities, in addition to those presently planned or listed for FY 62, additional funding will be necessary to equip the 30'x40' space simulator, and to initiate work on adaptations for the 60'x100' facility for Prospector testing.

FY 64

1. A 10'x20' space simulator.

An additional 10'x20' space simulator will be needed in FY 64 to handle developmental tests and studies for Prospector.

2. Spacecraft checkout facility.

An additional spacecraft checkout facility will be needed in FY 64 for Prospector work. Currently-planned and previously listed facilities will be used to such an extent that no checkout space adequate for Prospector will be available.

3. A radiation test facility.

It is expected that the radiation testing of prototypes of long life subsystems and components will be done on a relatively routine basis at JPL by FY 64. A facility should be established for this purpose.

It is not meant to imply that no radiation testing will be done before FY 64, but rather that such testing will be of a research nature and done at special radiation facilities at universities, etc., prior to that time.

FY 65, 66, 67

It is expected that the major facilities needed strictly for the support of this program will be established prior to 1965. Additional facilities requirements will certainly develop, but it is not intended here to create artificial requirements to cover contingencies.

LIFE SCIENCES FACILITIES

(Excluding Ground Instrumentation)

Launch Site Biomedical and Crew Holding Facility

This facility would provide for crew and biological preflight preparation and in some cases for post flight biomedical evaluation.

The facility will include provisions for the following:

1. Crew rest and sleeping
2. Kitchen and dining
3. Medical examination and treatment
4. ECG and EEG
5. Conferences and briefings
6. Physical conditioning
7. Material handling and specimen collection
8. Low pressure chamber
9. Personal equipment storage and maintenance
10. Biological laboratory
11. Administrative support
12. Animal holding and preparation

A rough estimate of requirements has been made in conjunction with the USAF Surgeon General's office and the USAF launch operations staff at Cape Canaveral. Total area required is approximately 30,000 square feet. A more detailed breakdown of the needs is available in memo form.

This facility does not include the X-ray, clinical laboratory, pharmacy and surgery facilities which, it is planned, would be provided as a part of the new base hospital to be constructed by USAF at Patrick Air Force Base.

It is probable that the existing hospital plan will have to be modified to meet NASA requirements. Some preliminary discussions have been held with USAF along these lines. It is important that a joint agreement be worked out to insure that NASA requirements are met. One such requirement is provision for treatment of injuries in the event of a major launch mishap.

Aerospace Medicine Facility at Ames Research Center

Laboratory facilities are required in which studies can be performed to acquire necessary data on Man and for assuring adequate baseline

controls for the in-flight biomedical experiments which are proposed. Specimens to be investigated would range from microbes through more complex animals such as mice up to and including chimpanzees.

Facilities are required in which bioinstrumentation techniques and equipment can be developed and tested.

A series of partial flight simulators are needed which would augment the existing flight simulators at ARC. These would be Research and Development Equipments of flexible internal configuration for the investigation of man-machine integration factors and definition of design parameters. Typical of these factors are:

1. Control and display relationships in the spacecraft for various mission phases in the areas of navigation, guidance, vehicle control, internal environment control, scientific observation, potential hazard evaluation, and mission task performance.

2. Problems of maintenance and trouble shooting.

3. Control and display relationships for ground operations and communications.

4. Control and display relationships pertaining to the operation of remote vehicles, including the effects of communication time lag, radio noise, and other information degrading phenomena.

5. Cabin design factors to insure crew habitability and social adjustment.

In addition, supporting laboratories, data analysis equipment and subject preparation facilities currently available at ARC would be augmented as required.

A tentative plan has been prepared for such a facility which would provide about 90,000 square feet and would support the work of 60 professional investigators and their supporting personnel (about 200 total personnel).

Radiation Research Facility

It is proposed to augment the HILAC (Heavy Ion Linear ACcelerator) at the University of California at Berkeley to enable better partial ground simulation of primary cosmic radiation. The C of F cost in FY 62 will be $500,000. It is believed that augmenting the facility and supporting the R & D at Berkeley is the most economical way to ensure that the control and shielding experiments needed to calibrate the flight data and provide shielding effectiveness design criteria.

High Vacuum Lunar Environment Chamber for R&D Support of Manned Lunar Landing

To support the development of technology for the manned lunar landing program a large high vacuum (10^{-8} mm Hg) multipurpose facility is vitally needed in which the lunar environment can be approximated. Critically needed research in this chamber paces the design of adequate lunar equipment for man's use. Joint use of this facility is contemplated (JPL, Industry, Universities). This facility is required in addition to any facilities needed for spacecraft checkout, crew training, and propulsion development.

Experimental investigations to be conducted include:

1. Materials computibility and characteristics in high vacuum.

2. Research and development to define equipment design parameters to permit men to study the lunar surface and subsurface characteristics. Such equipment includes:

   a. Surface vehicles, manned and remote controlled
   b. Instruments useful in exobiology
   c. Protective systems (suits, etc.)
   d. Drills, shovels

3. Perfection and testing of decontamination techniques to protect the lunar environment.

4. It is possible, although unlikely, that the lunar surface may contain materials which should not be returned to earth in an uncontrolled manner. Protection and decontamination techniques would have to be developed.

5. The development of training techniques for lunar surface investigators proving feasibility of equipment technology.

6. Development of methods to enable man to assess the economic potential of the moon.

7. Determination of the interaction of equipment with the lunar surface.

8. Possible development of devices enabling man to "see" nonvisual radiations in the lunar environment.

To meet these and future requirements the facility should have the following characteristics:

1. At least 60' Dia hemispherical or 40' high cylinder.

2. Vacuum: 10^{-8} mm Hg (This is essential to accomplish materials testing.) At least this order of vacuum is needed to insure checking of known critical phenomena.

3. Radiant sources to simulate sunlight must be provided.

4. The walls should be cryogenically cooled to simulate deep space radiation sink, and as a final stage pump.

5. Provision must be made to degas and introduce material to simulate the lunar surface to a depth of several feet. The characteristics of this material would be changed to reflect the best available knowledge of lunar surface characteristics.

6. Adequate safety features must be incorporated.

Problem areas:

1. Difficulty in measuring very low pressures accurately.

2. In addition to large vacuum diffusion pumps it will be required first to bake out the interior surface using special heating apparatus built in to the chamber, then employ both liquid gas freeze out plates and other techniques to maintain 10^{-8} mm Hg.

3. The pump down time will be long, on the order of weeks. Therefore several airlocks will be required which can be pumped rapidly, while the vacuum is continuously maintained in the large chamber.

4. For safety special recovery equipment must be provided and an M.D. must be on duty at all times when men are in the chambers. Emergency medical facilities must be nearby the chamber.

5. Propulsion systems tests cannot be carried on in this chamber.

Because of the large amount of effort in the engineering aspects of Life Science which will be devoted to the use of this facility and because of the proximity of JPL, it is recommended that this facility be constructed at the Ames Research Center.

Completion should be scheduled for July of 1963. Total facility cost, exclusive of special test equipment is estimated at $12 million.

Recovery Site Crew Medical and Holding Facility

Facilities will be required at or near the landing site(s) planned for the manned missions. If landing is to be near AMR, these facilities can be largely incorporated into the biomedical facility at Cape Canaveral. For other landing sites, facilities must be constructed.

The following provisions are seen to be required:

1. Crew rest and sleeping
2. Conference and debriefing
3. Kitchen and dining
4. Medical examination
5. Specimen collection and clinical laboratory
6. X-ray and surgery
7. ECG and EEG

Flight and Ground Medical Crew Training Support

This plan assumes that available NASA and DOD facilities will be used for most of the training program (such as the Flight Operations Facility of the new Manned Space Flight Center). It will be necessary to augment these facilities with special mission and part-task simulator facilities to aid in training crews in the procedures and skills peculiar to the manned lunar landing and prior missions. DOD facilities which would be used include the USAF Aerospace Medical Center (altitude chambers, classrooms, laboratories) and the centrifuges at Wright Patterson AFB and Johnsville.

ADVANCED TECHNOLOGY
GROUND SUPPORT FACILITIES

Low-Frequency Environmental Noise Facility

This facility provides for a high-intensity low frequency (1-50 cycles per second) noise source to be located at an existing noise facility at the Langley Research Center, to study the effects of characteristics Nova noise on vehicle structures and systems and effects on shelter structures. Estimated construction time is 6 months.

Space Radiation Effects Laboratory

This facility consists of two high-energy particle accelerators and associated equipment for simulation of radiation belt and solar flare environment. A diffuse-beam 600 mev proton accelerator is the principal item of equipment. The second and smaller accelerator is a 2-10 mev linear electron accelerator. The facility is needed for:

a. Study of effectiveness and resistance to radiation damage of materials used in composite spacecraft shielding design.

b. Study of radiation effects on spacecraft materials, such as ablative heat shields, seals, lubricants, glasses, and effects on surface characteristics such as emissivity.

c. Study of secondary radiation behind shielding materials.

d. Study of degradation of performance of solar cells, transistors, infrared detectors, masers, and assemblies.

e. Study of new shielding techniques such as electrostatic and electromagnetic shielding.

Construction time is estimated at 2 to $2\frac{1}{2}$ years.

Additional Power Supply and Improved Arc Chamber for Existing 10 Megawatt Arc Tunnel

The Langley 10-megawatt arc tunnel is nearing completion and scheduled to operate shortly. It will be capable of stream enthalpies corresponding to re-entry at satellite velocity. To study adequately the materials and structural problems of the Apollo re-entry module higher stream enthalpies are required approaching twice those for satellite re-entry. The proposed

equipment is to improve the ability of the existing facility to get data on heat shield performance and related structural problems of direct application to Apollo. Estimated time to initial operation is 10 months.

Environmental Research Facilities for Spacecraft Components and Materials

This project consists of an array of small vacuum chambers (1-50 cubic feet) with associated equipment and instrumentation for the study of spacecraft materials and structural components subjected to hard vacuum and simulated thermal radiation. Approximately 40 vacuum chambers are needed in order to carry out simultaneously a large number of experiments, each of days, weeks, or months duration. The smaller, less complicated components of this facility can be procured and put into operation immediately. Facility is estimated to be completely equipped in 16 months.

Lunar Landing Test Facility

This facility consists of a large outdoor assembly involving an overhead track 200 feet high by 800 feet long supporting a powered carriage and winch system from which is suspended the independently powered manned test vehicle. Horizontal velocities up to 100 feet per second and vertical velocities up to 30 feet per second would be provided. Provision would be made for partial support of the weight of the test vehicle to simulate the moon's low gravitational field. This facility is urgently needed to study guidance and control, piloting technique, and landing impact problems of lunar landing. Completion time is estimated to be 1 to $1\frac{1}{2}$ years.

Particle Accelerator for Simulation of Micrometeoroid Impact

This facility consists of an electrostatic particle accelerator to achieve microparticle velocities up to about 80,000 feet per second. Existing particle accelerators using the light gas gun principle have been brought to the point that speeds of 30,000 feet per second have been achieved and show some promise for going even higher to perhaps 40,000 feet per second. To go appreciably higher than that requires a different principle of acceleration (natural meteoroids have speeds between 30,000 and 250,000 feet per second). Construction time is estimated to be slightly more than 1 year.

Stabilization and Control Equipment Laboratory

This facility includes inertial simulators for instrument mounting; electronic simulation facilities for closed-loop integrated systems studies; medium-high-vacuum equipment for long-time-operation; low torque control system investigation; long-throw optical facilities for use with simulators; equatorial and time-drive mounts for use with sun, star, and planet seekers;

magnetic field control to simulate the fields encountered in space; and a special building to accommodate the long-throw optical arm and other special requirements. This facility is needed at the Langley Research Center for the proper support of Atlas-Agena re-entry flights and for augmented direct support of guidance and control problems of Apollo.

Procurement and use of many elements of the equipment would begin immediately. Estimated completion of facility, including the building, is 1 year.

Space Propulsion Test Facility

This facility consists of a vacuum tank of 300,000 cu. ft. volume provided with cooled walls, movable solar radiation sources, a three-axis table, and analog control equipment. It is needed at the Lewis Research Center to study attitude-control rocket motors, solar electric power generation, propellant tank problems including insulation, and propulsion system interactions. Total construction time is estimated to be 3 years.

Turbo-pump Facility

This project involves expansion of existing Lewis Plum Brook propellant facilities for handling and storage of cryogenics and added instrumentation. It is needed to study the design problems of the required large turbo pumps for hydrogen engines for Nova vehicles. Estimated completion time is 2 years.

Equipment to Study Propulsion System and Component Interaction

This proposal is for analogue computer equipment capable of dealing with point mass and real-body motions under the influence of propulsive forces, and inertia and gravity torques, with reference to the dynamics of various elements of the space vehicle, i.e. lunar landing and take-off configurations and the launch vehicle system.

Environmental Chamber for Study of Energy Converters

This facility consists of a 20-foot-diameter, 30-foot-long vacuum chamber with associated equipment and instrumentation for studying the performance of energy converters such as solar collectors and cells and fuel cells in the simulated space environment. Estimated construction time is 1 year.

Propellant Expulsion Facility

This proposal is for extension of existing Lewis facilities for the study of techniques for pressurization and expulsion of propellants from full-scale, multiple, interconnected propellant tanks under static and dynamic conditions. Estimated completion time is 1 year.

Meteoroid Sensor and Instrument Facility

This facility consists of a 15-foot-diameter, 30-foot-long vacuum chamber for the study and development of meteoroid sensors and packages for free-flight experiments. Completion time is 1 year or less.

Radio-Wave Attenuation Facility

This facility consists of a large-volume chamber with altitude capability (not high vacuum) for the creation of realistic rocket plumes. It is needed for the study of rocket exhaust attenuation of EM signals as in the employment of radio altimeter to measure height above lunar surface. Completion time is 1 year.

Equipment for Study of Electromagnetic Shielding Against Charged Particle Radiation

This proposal is for cryogenic equipment to produce temperatures down to one-degree Kelvin for the creation of strong fields with superconducting electromagnets. This equipment is needed to study the potentialities of unconventional shielding techniques against penetrating space radiation. Acquisition of equipment is one year or less.

Dust Tank

This facility consists of a 10-foot-diameter, 20-foot-long hard-vacuum chamber with provision for the electrostatic charging of dust particles, simulating the potential lunar environment experienced by a landing vehicle. The facility is needed for study of phenomena encountered with neutral and charged particles and interactions with spacecraft materials and components. Completion time is 1 year.

CRITICAL FY 62 ACTIONS

GROUND SUPPORT FACILITIES

Engine, Motor, and Stage, Static Test Facilities:

(1) Start first stage liquid NOVA static test facilities.

(2) Start first stage liquid C-3 static test facilities.

(3) Start F-1 acceptance stands.

(4) Start J-2 acceptance stands.

(5) Start Y-1 test facilities.

(6) Start second stage liquid NOVA static test facilities.

(7) Start first stage solid NOVA static test facilities.

(8) Start C-3 solid first stage static test facilities.

Launch Facilities:

(1) Complete launch site sound level analysis.

(2) Define NASA-DOD range responsibilities and authority, including funding agreements for land extension.

(3) Start land acquisition action necessary to facilities construction.

(4) Start criteria, design and initial site preparation for C-3 and NOVA liquid and solid launch facilities.

(5) Start off-shore AMR core drilling.

(6) Obtain approval for incremental C of F funding.

(7) Obtain Department of Labor support in the further limitation and control of walk-outs, strikes, etc. at the launch sites.

(8) Start analysis of nuclear power supply safety and handling.

(9) Start engineering prove-in of long distance digital transmission.

(10) Start defining down range launch support instrumentation requirements.

Ground Instrumentation:

(1) Start instrumentation for Mercury 18 orbit mission.

(2) Start augmentation of deep space instrumentation facility.

(3) Define communications and tracking systems in spacecraft.

(4) Start advanced development of large and lunar transponder systems.

Apollo Spacecraft Ground Support Facilities:

(1) Start Manned Space Flight Center.

(2) Start pre-flight operations facilities.

(3) Start spacecraft propulsion checkout facility.

Life Science:

(1) Start 30' x 40' space simulator.

(2) Start two 10' x 20' space simulators.

(3) Start large high frequency shaker.

(4) Start large low frequency shaker.

(5) Start two acoustic test chambers.

(6) Start second spacecraft facility at AMR.

Life Science Facilities:

(1) Start launch site biomedical and crew holding facility.

(2) Start aero-space medical facility at Ames Research Center.

(3) Start modification of heavy ion linear accelerator at University of California.

(4) Start high vacuum lunar and environment chamber.

(5) Start negotiations for use of DOD facilities and purchase of special equipment for flight and control medical crew training support.

Advanced Technology:

(1) Start space radiation effects laboratory.

(2) Start low frequency environment noise facility.

(3) Start spacecraft components and materials environment research facility.

(4) Start lunar landing test facility.

(5) Start particle acceleration for simulation of micrometeroid impact.

(6) Start stabilization and control equipment laboratory.

(7) Start space propulsion test facility.

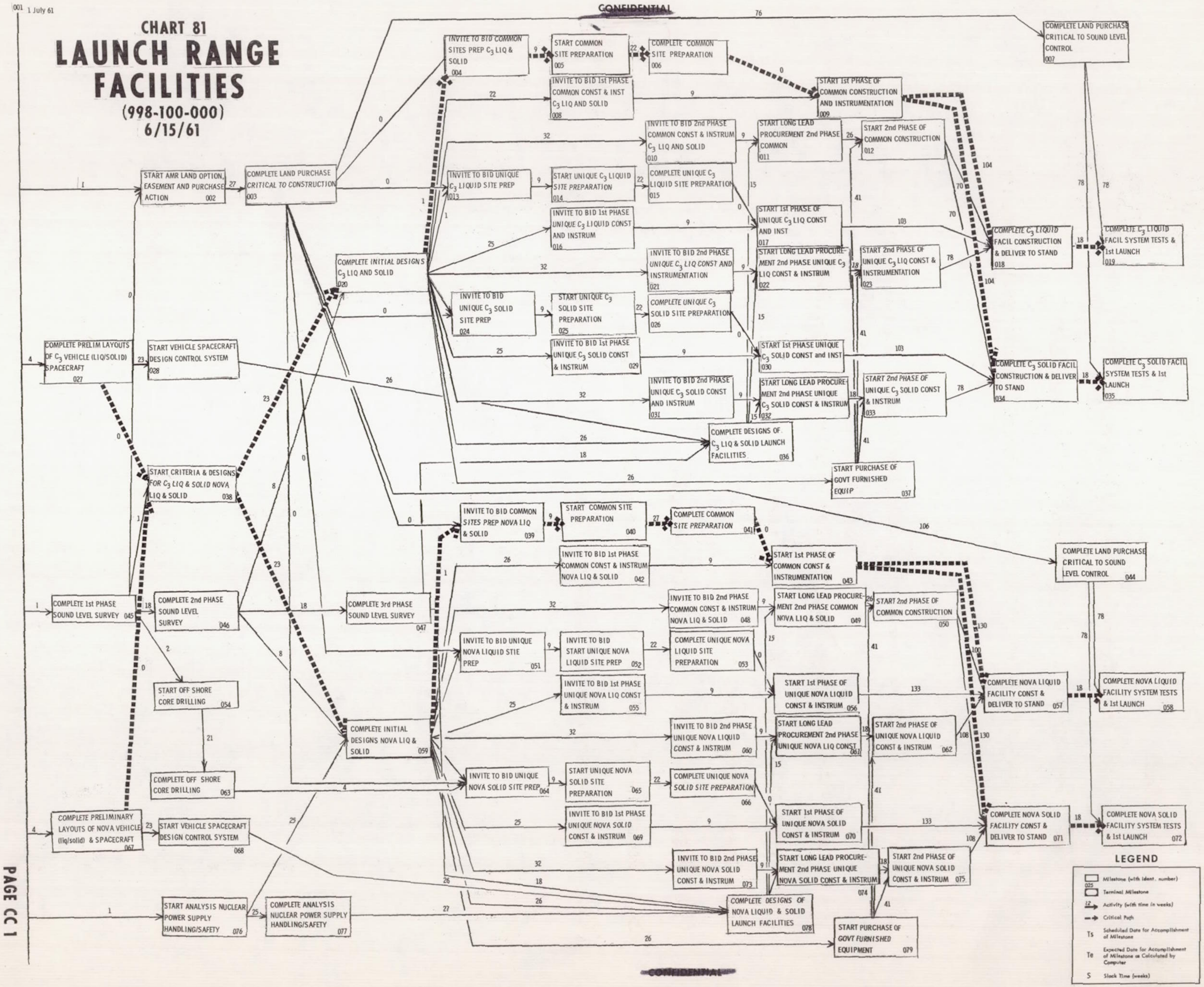
(8) Start turbo pump facility.

(9) Start propellant expulsion facility.

(10) Start meteroid sensor and instrument facility.

(11) Start radio wave attenuation facility.

CHART 81
LAUNCH RANGE FACILITIES
(998-100-000)
6/15/61



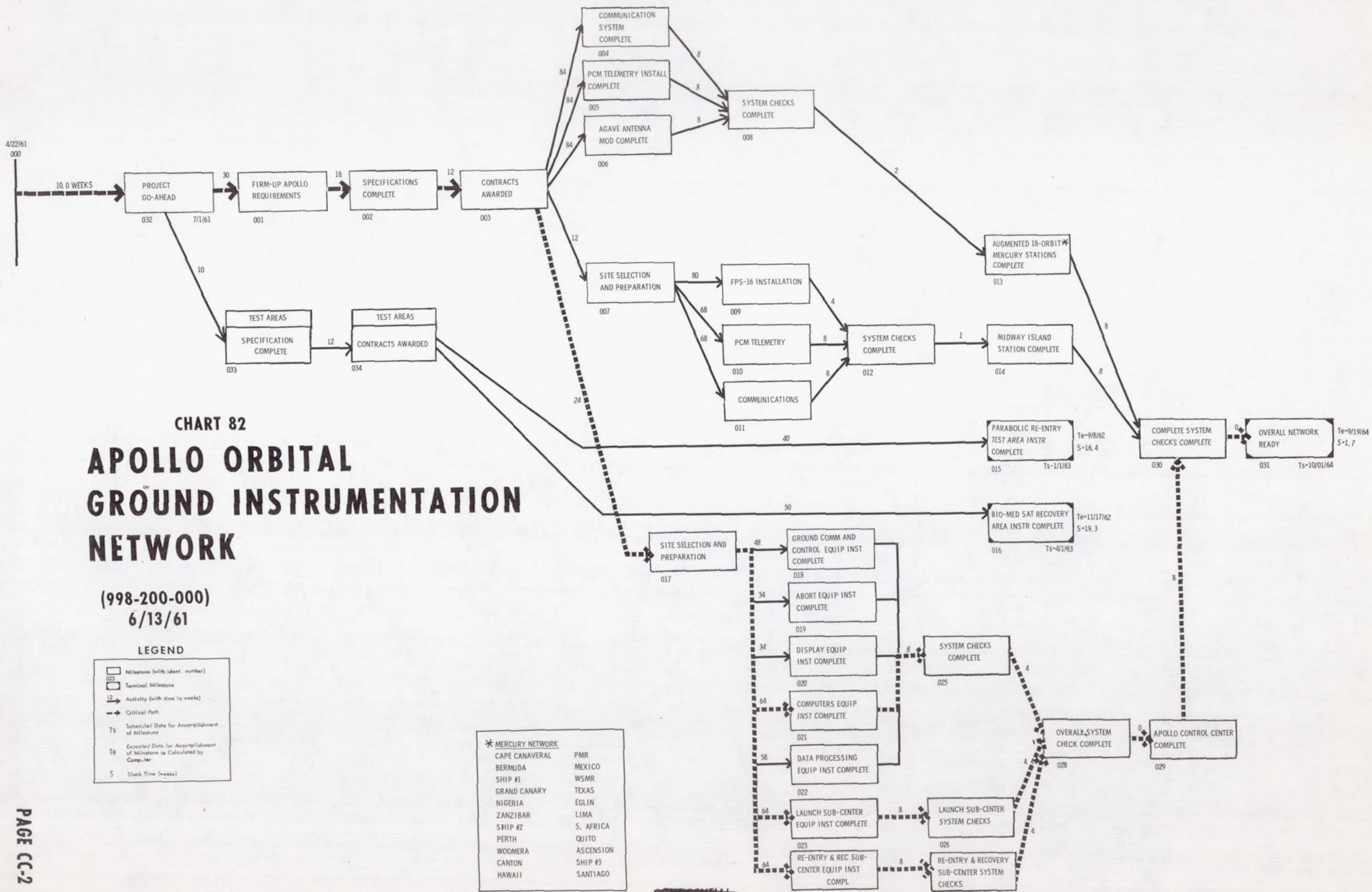


CHART 82

APOLLO ORBITAL GROUND INSTRUMENTATION NETWORK

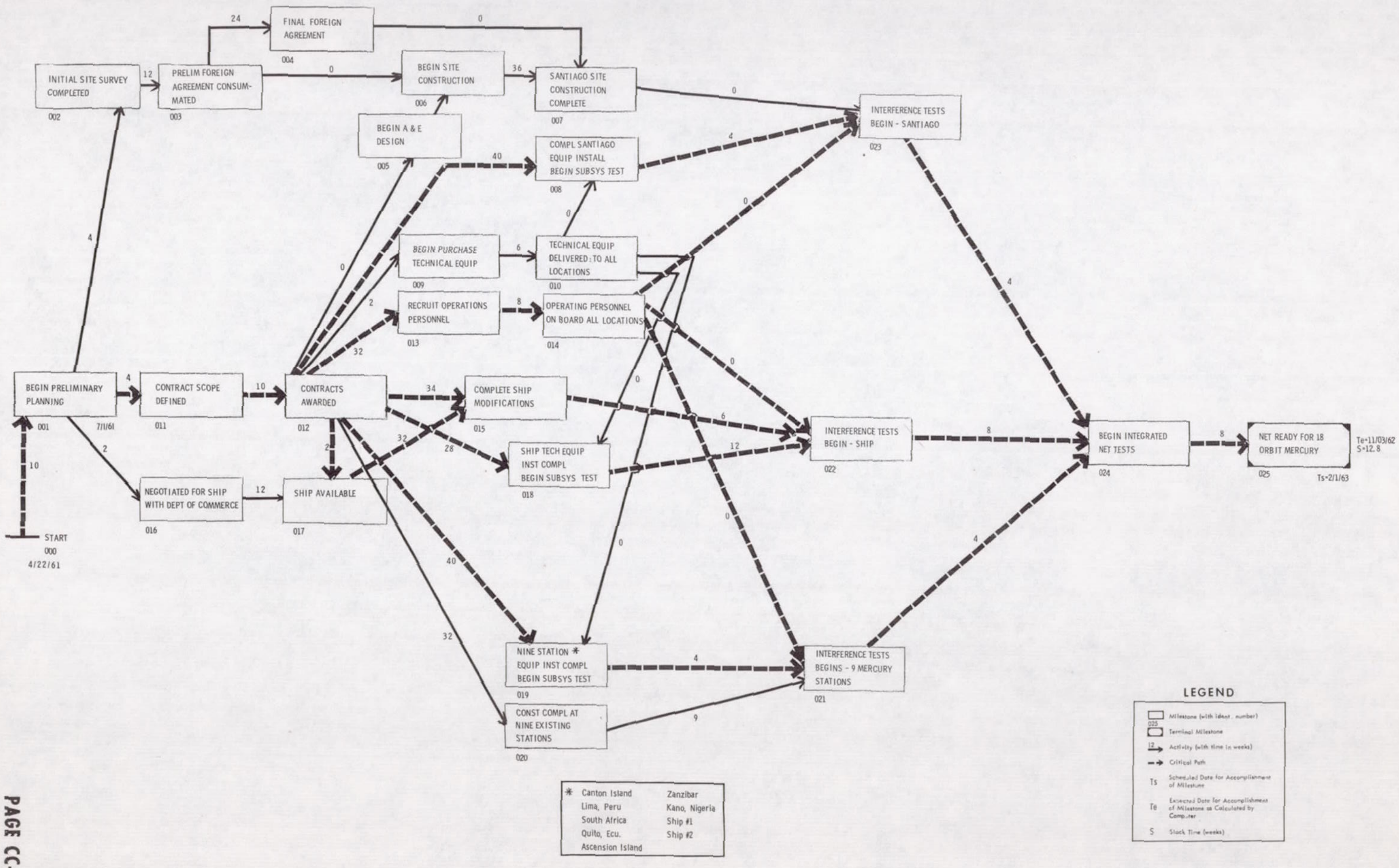
(998-200-000)
6/13/61

[redacted]

CHART 83

18 ORBIT MERCURY GROUND INSTRUMENTATION NETWORK

(998-300-000)
6/13/61



[redacted]

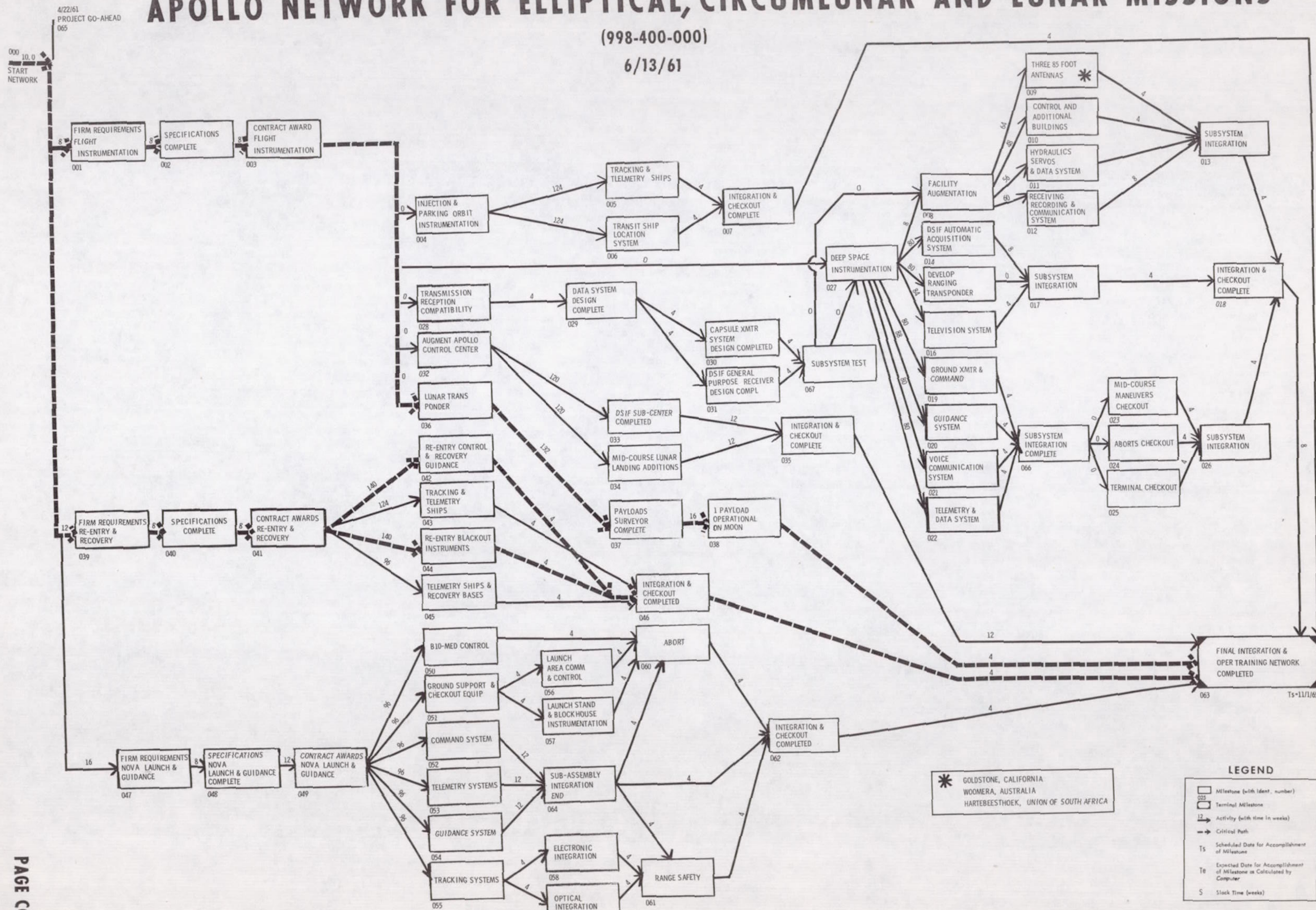
CONFIDENTIAL

CHART 84

APOLLO NETWORK FOR ELLIPTICAL, CIRCUMLUNAR AND LUNAR MISSIONS

(998-400-000)

6/13/61



CONFIDENTIAL

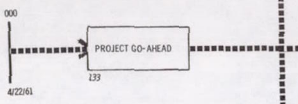
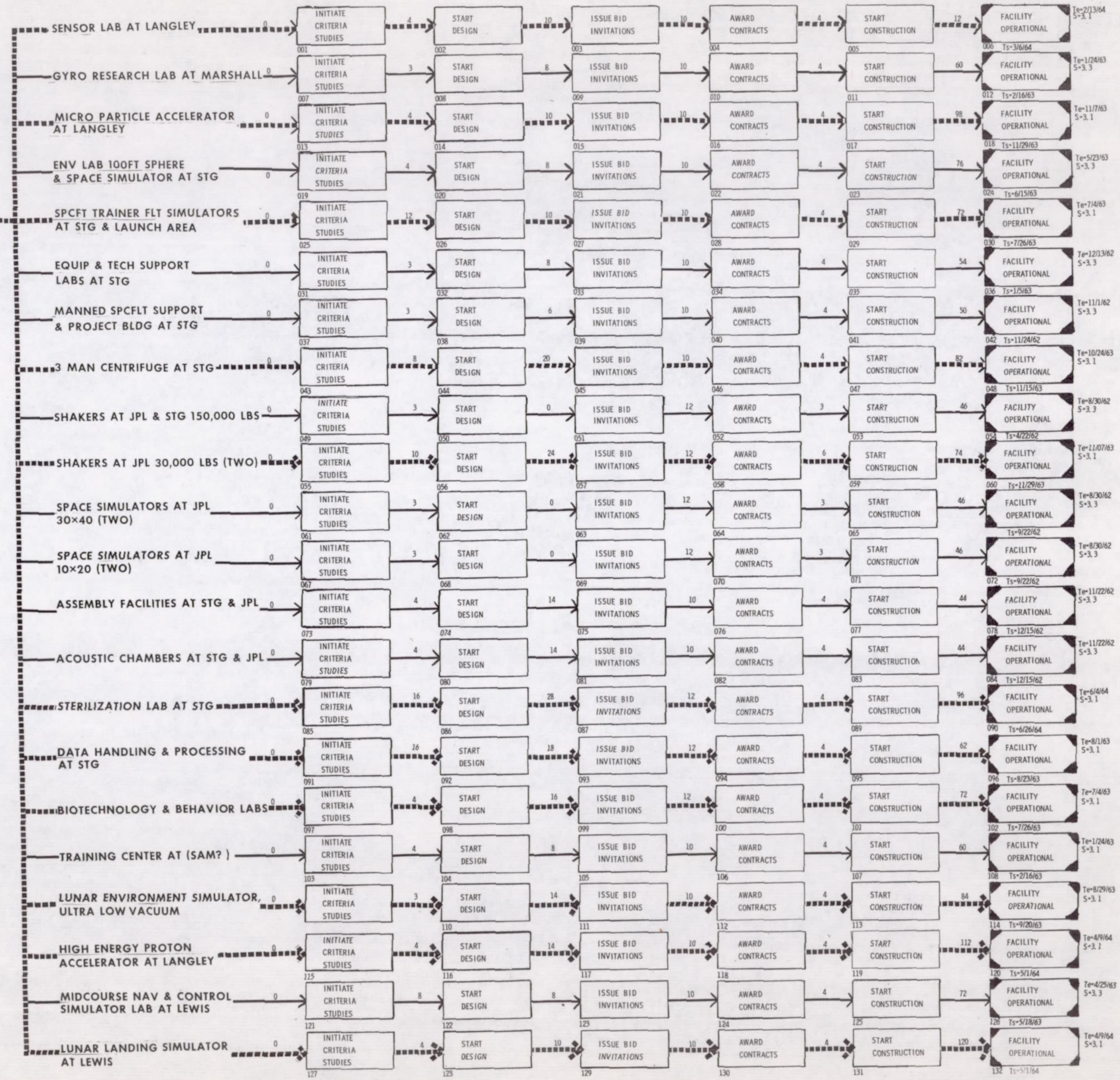


CHART 85

(998-500-000)

6/2/61

FACILITIES:
APOLLO SPACECRAFT UNMANNED LUNAR SPACECRAFT LIFE SCIENCE ADVANCED TECHNOLOGY



LEGEND

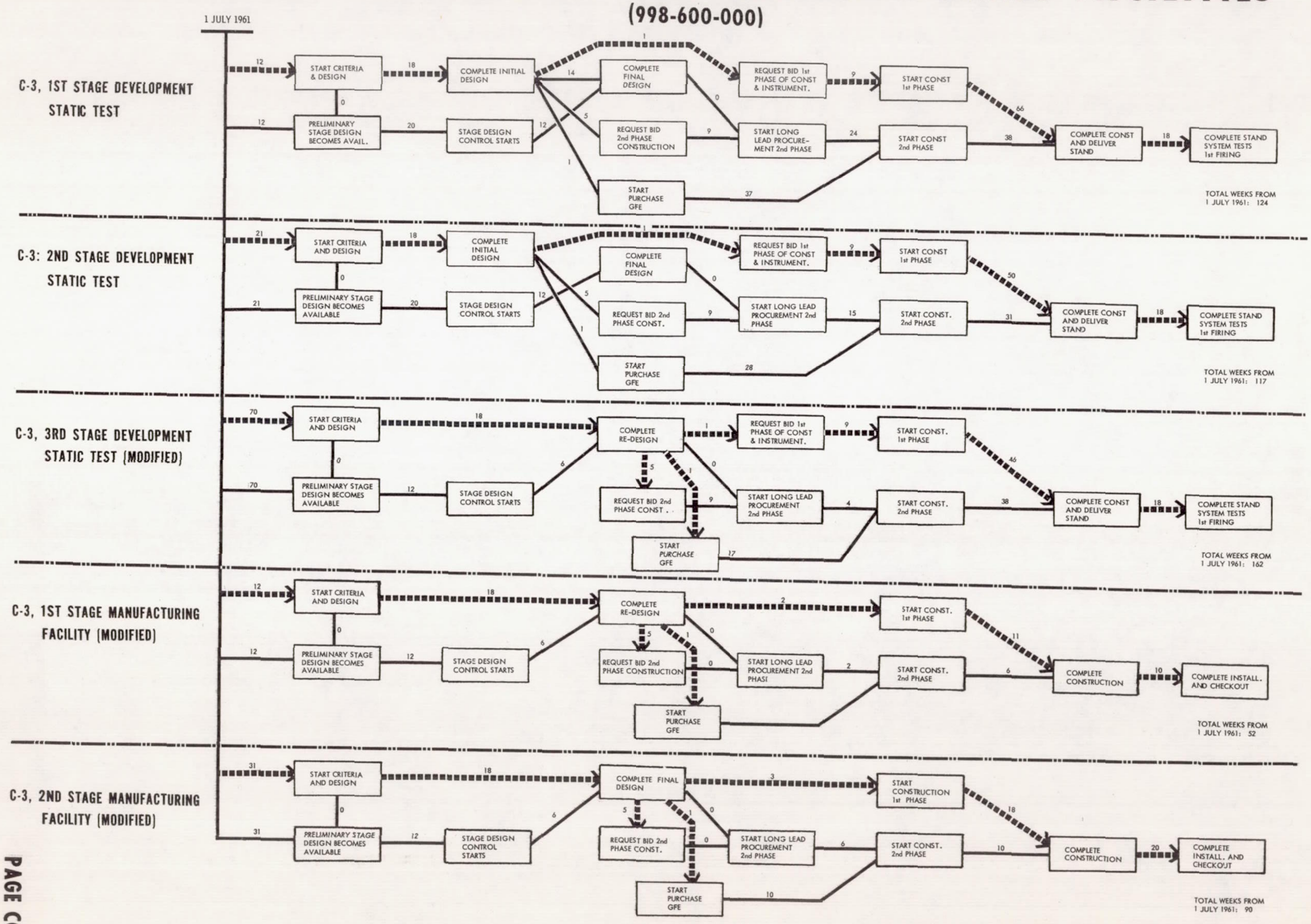
- Milestone (with ident. number)
- Terminal Milestone
- Activity (with time in weeks)
- Critical Path
- Ts — Scheduled Date for Accomplishment of Milestone
- Te — Expected Date for Accomplishment of Milestone as Calculated by Computer
- S — Slack Time (weeks)

CHART 86

6/15/61

C-3 LIQUID STAGE STATIC AND MANUFACTURING FACILITIES

(998-600-000)



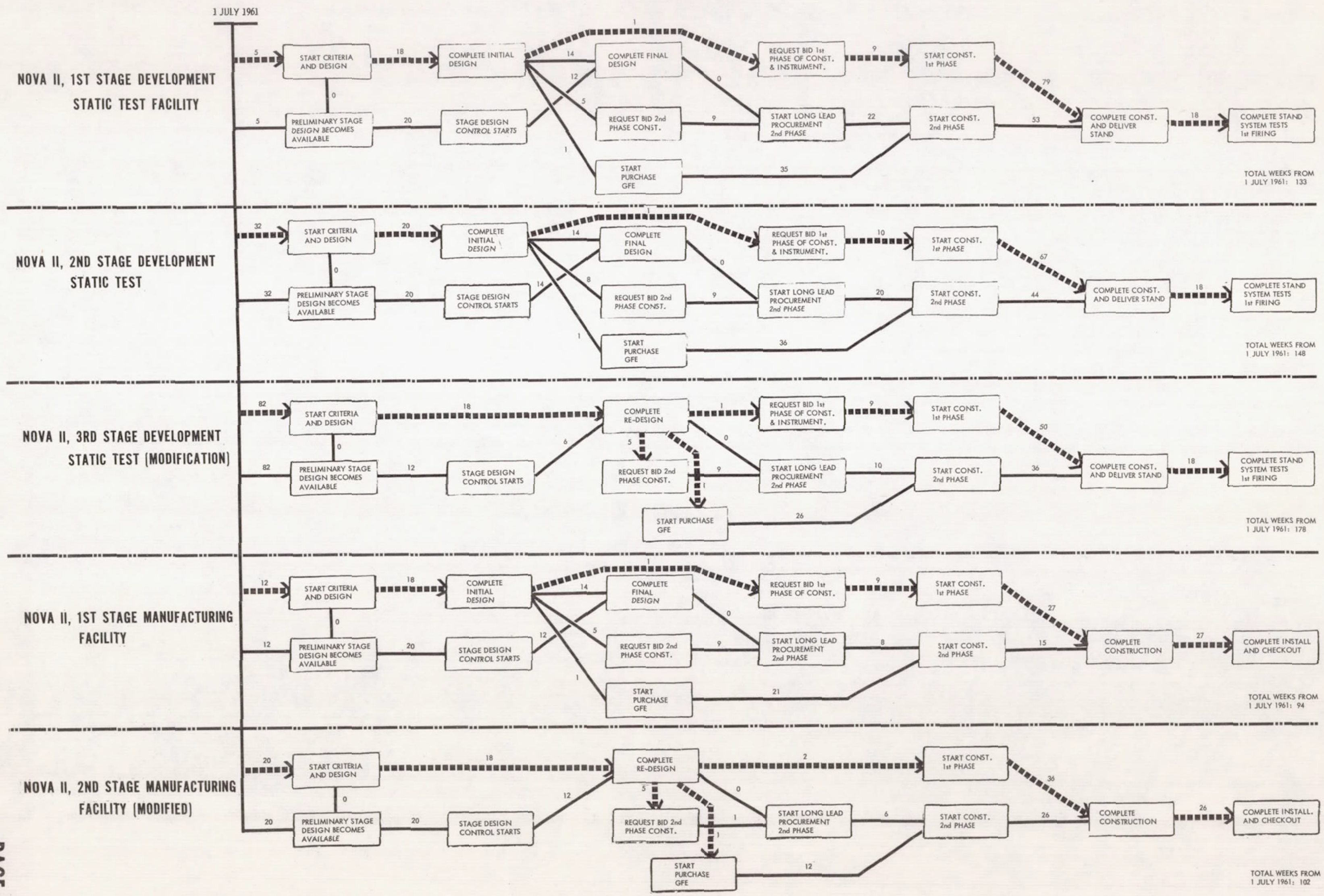
CO Restriction/Classifica

CHART 87

6/15/61

NOVA LIQUID STAGE STATIC AND MANUFACTURING FACILITIES

998-700-000



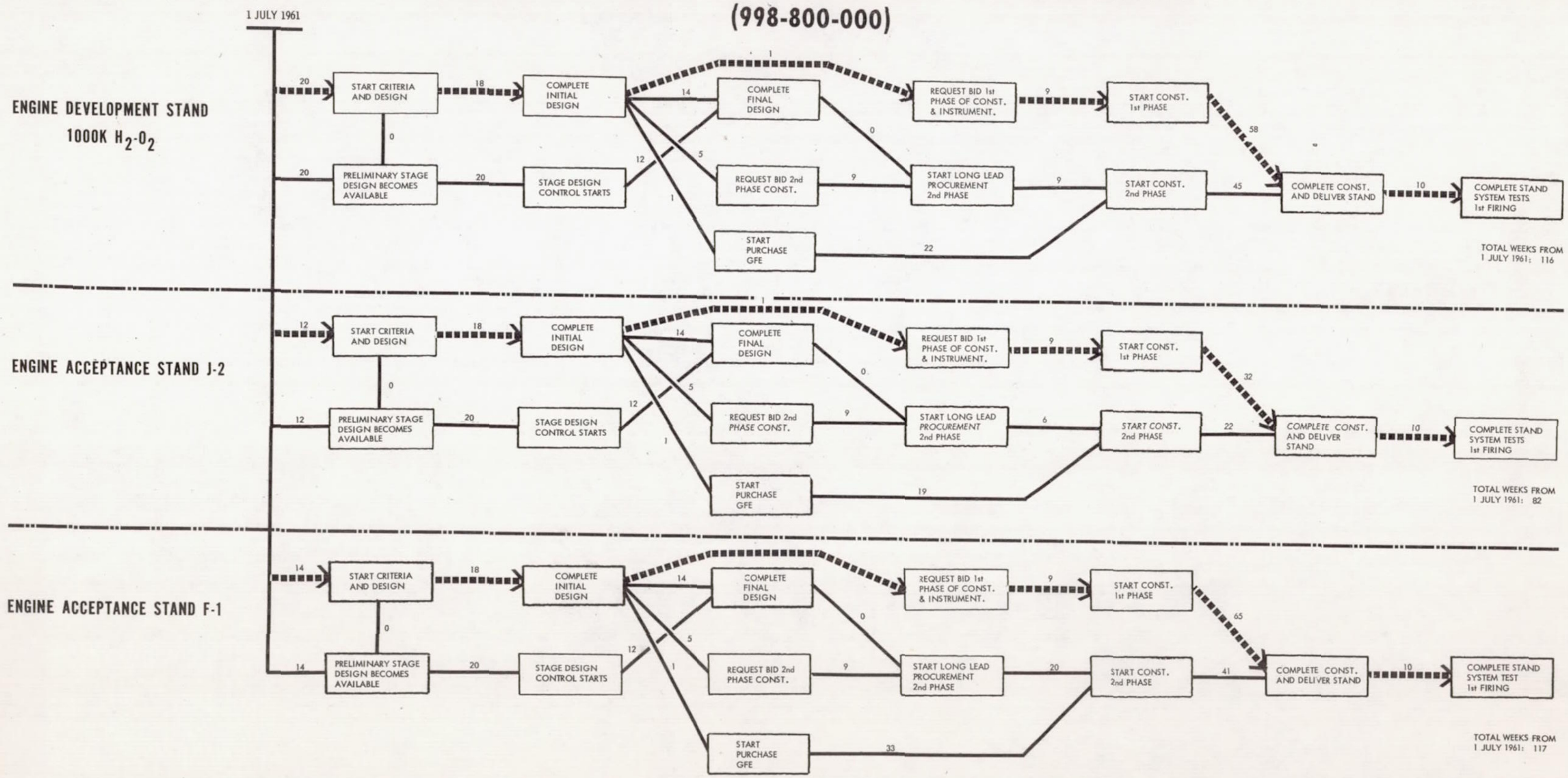
~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

CHART 88 6/15/61

LIQUID ENGINE STATIC FACILITIES

(998-800-000)



~~CONFIDENTIAL~~

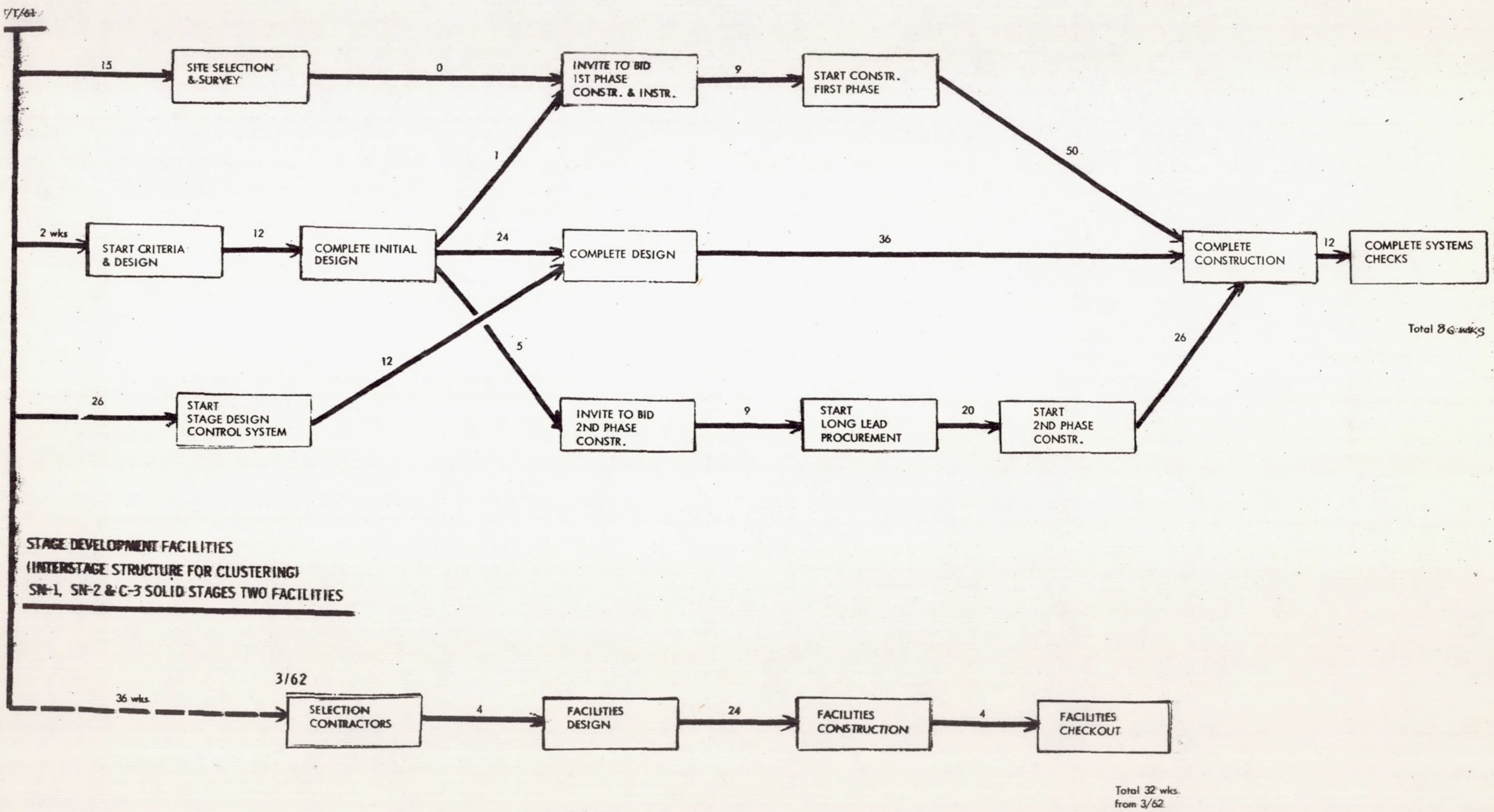
SN-1 SN-2 & C-3 SOLID STAGES

STATIC TEST FACILITIES

1 BLOCKHOUSE, 3 TEST POSITIONS

CHART 89

998-900-000



CC-9

~~CONFIDENTIAL~~

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
998-200-000	NETWORK START	0/00/00	0/00/00			1.7
998-200-032	PROJECT GO-AHEAD	7/01/61	7/13/61			1.7
998-200-001	FIRM-UP APOLLO REQUIREMENTS	1/27/62	2/08/62			1.7
998-200-002	SPECIFICATIONS COMPLETE	6/02/62	6/14/62			1.7
998-200-003	CONTRACTS AWARDED	8/25/62	9/06/62			1.7
998-200-017	SITE SELECTION AND PREPARATION	2/09/63	2/21/63			1.7
998-200-024	RE-ENTRY & REC SUB-CENTER EQUIP INST COMPL	5/02/64	5/14/64			1.7
998-200-023	LAUNCH SUB-CENTER EQUIP INST COMPLETE	5/02/64	5/14/64			1.7
998-200-021	COMPUTERS EQUIP INST COMPLETE	5/02/64	5/14/64			1.7
998-200-027	RE-ENTRY & RECOVERY SUB-CENTER SYSTEM CHECKS	6/27/64	7/09/64			1.7
998-200-026	LAUNCH SUB-CENTER SYSTEM CHECKS	6/27/64	7/09/64			1.7
998-200-025	SYSTEM CHECKS COMPLETE	6/27/64	7/09/64			1.7
998-200-028	OVERALL SYSTEM CHECK COMPLETE	7/25/64	8/06/64			1.7
998-200-029	APOLLO CONTROL CENTER COMPLETE	7/25/64	8/06/64			1.7
998-200-031	OVERALL NETWORK READY	9/19/64	10/01/64	10/01/64		1.7
998-200-030	COMPLETE SYSTEM CHECKS COMPLETE	9/19/64	10/01/64			1.7
998-200-007	SITE SELECTION AND PREPARATION	11/17/62	12/20/62			4.7
998-200-009	FPS-16 INSTALLATION	5/30/64	7/02/64			4.7
998-200-012	SYSTEM CHECKS COMPLETE	6/27/64	7/30/64			4.7
998-200-014	MIDWAY ISLAND STATION COMPLETE	7/04/64	8/06/64			4.7
998-200-022	DATA PROCESSING EQUIP INST COMPLETE	3/21/64	5/14/64			7.7
998-200-004	COMMUNICATION SYSTEM COMPLETE	4/04/64	5/28/64			7.7
998-200-006	AGAVE ANTENNA MOD COMPLETE	4/04/64	5/28/64			7.7
998-200-005	PCM TELEMETRY INSTALL COMPLETE	4/04/64	5/28/64			7.7
998-200-008	SYSTEM CHECKS COMPLETE	5/30/64	7/23/64			7.7

[redacted]

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
998-200-013	AUGMENTED 18-ORBIT MERCURY STATIONS COMPL	6/13/64	8/06/64			7.7
998-200-010	PCM TELEMETRY	3/07/64	6/04/64			12.7
998-200-011	COMMUNICATIONS	3/07/64	6/04/64			12.7
998-200-033	TEST AREA SPECIFICATIONS COMPLETE	9/09/61	1/02/62			16.4
998-200-034	TEST AREA CONTRACTS AWARDED	12/02/61	3/27/62			16.4
998-200-015	PARABOLIC RE-ENTRY TEST AREA INSTR COMPL	9/08/62	1/01/63	1/01/63		16.4
998-200-018	GROUND COMM & CONTROL EQUIP INST COMPL	1/11/64	5/14/64			17.7
998-200-016	BIO-MED SAT RECOVERY AREA INSTR COMPL	11/17/62	4/01/63	4/01/63		19.3
998-200-020	DISPLAY EQUIP INST COMPLETE	10/05/63	5/14/64			31.7
998-200-019	ABORT EQUIP INST COMPLETE	10/05/63	5/14/64			31.7

[redacted]

[redacted]

SMS SYSTEM

DATE 6/02/61 WEEK 126.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
998-300-000	START	0/00/00	0/00/00			12.8
998-300-001	BEGIN PRELIMINARY PLANNING	7/01/61	9/28/61			12.8
998-300-011	CONTRACT SCOPE DEFINED	7/29/61	10/26/61			12.8
998-300-012	CONTRACTS AWARDED	10/07/61	1/04/62			12.8
998-300-017	SHIP AVAILABLE	10/21/61	1/18/62			12.8
998-300-018	SHIP TECH EQUIP INST COMPL BEGIN SUB SYSTEM TEST	4/21/62	7/19/62			12.8
998-300-013	RECRUIT OPERATIONS PERSONNEL	5/19/62	8/16/62			12.8
998-300-015	COMPLETE SHIP MODIFICATIONS	6/02/62	8/30/62			12.8
998-300-008	COMPL SANTIAGO EQUIP INST BEGIN SUB SYSTEM TEST	7/14/62	10/11/62			12.8
998-300-019	NINE STATION EQUIP INST COMPL BEGIN SUB SYSTEM T	7/14/62	10/11/62			12.8
998-300-014	OPERATING PERSONNEL ON BOARD ALL LOCATIONS	7/14/62	10/11/62			12.8
998-300-022	INTERFERENCE TESTS BEGIN - SHIP	7/14/62	10/11/62			12.8
998-300-023	INTERFERENCE TESTS BEGIN - SANTIAGO	8/11/62	11/08/62			12.8
998-300-021	INTERFERENCE TESTS BEGINS - 9 MERCURY STATIONS	8/11/62	11/08/62			12.8
998-300-024	BEGIN INTEGRATED NET TESTS	9/08/62	12/06/62			12.8
998-300-025	NET READY FOR 18 ORBIT MERCURY	11/03/62	1/31/63	2/01/63		12.8
998-300-016	NEGOTIATED FOR SHIP WITH DEPT OF COMMERCE	7/15/61	10/26/61			14.8
998-300-009	BEGIN PURCHASE TECHNICAL EQUIPMENT	10/21/61	2/01/62			14.8
998-300-010	TECHNICAL EQUIPMENT DELIVERED TO ALL LOCATIONS	4/07/62	7/19/62			14.8
998-300-020	CONST COMPL AT NINE EXISTING STATIONS	5/19/62	9/06/62			15.8
998-300-005	BEGIN A&E DESIGN	10/07/61	2/01/62			16.8
998-300-006	BEGIN SITE CONSTRUCTION	11/04/61	3/01/62			16.8
998-300-007	SANTIAGO SITE CONSTRUCTION COMPLETE	7/14/62	11/08/62			16.8
998-300-002	INITIAL SITE SURVEY COMPLETED	7/29/61	12/07/61			18.8
998-300-003	PRELIM FOREIGN AGREEMENT CONSUMMATED	10/21/61	3/01/62			18.8

[redacted]

[redacted]

SMS SYSTEM

DATE 6/02/61 WEEK 126.2 . SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
998-300-004	FINAL FOREIGN AGREEMENT	4/07/62	11/08/62			30.8

[redacted]

~~CONFIDENTIAL~~

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
998-400-000	START NETWORK	0/00/00	0/00/00			50.3
998-400-065	PROJECT GO-AHEAD	7/01/61	6/18/62	7/01/61		50.3
998-400-001	FIRM REQUIREMENTS FLIGHT INSTRUMENTATION	8/26/61	8/13/62			50.3
998-400-039	FIRM REQUIREMENTS RE-ENTRY & RECOVERY	9/23/61	9/10/62			50.3
998-400-002	SPECIFICATIONS COMPLETE	10/21/61	10/08/62			50.3
998-400-040	SPECIFICATIONS COMPLETE	11/18/61	11/05/62			50.3
998-400-036	LUNAR TRANS PONDER	12/16/61	12/03/62			50.3
998-400-003	CONTRACT AWARD FLIGHT INSTRUMENTATION	12/16/61	12/03/62			50.3
998-400-041	CONTRACT AWARDS RE-ENTRY & RECOVERY	1/13/62	12/31/62			50.3
998-400-037	4 PAYLOADS SURVEYOR COMPLETE	6/27/64	6/14/65			50.3
998-400-042	RE-ENTRY CONTROL & RECOVERY GUIDANCE	9/19/64	9/06/65			50.3
998-400-044	RE-ENTRY BLACKOUT INSTRUMENTS	9/19/64	9/06/65			50.3
998-400-038	1 PAYLOAD OPERATIONAL ON MOON	10/17/64	10/04/65			50.3
998-400-046	INTEGRATION & CHECKOUT COMPLETED	10/17/64	10/04/65			50.3
998-400-063	FINAL INTEGRATION & OPER TRAINING NETWORK COMPL	11/14/64	11/01/65	11/01/65		50.3
998-400-032	AUGMENT APOLLO CONTROL CENTER	12/16/61	1/28/63			58.3
998-400-033	DSIF SUB-CENTER COMPLETED	4/04/64	5/17/65			58.3
998-400-034	MID-COURSE LUNAR LANDING ADDITIONS	4/04/64	5/17/65			58.3
998-400-035	INTEGRATION & CHECKOUT COMPLETE	6/27/64	8/09/65			58.3
998-400-043	3 TRACKING & TELEMETRY SHIPS	5/30/64	9/06/65			66.3
998-400-047	FIRM REQUIREMENTS NOVA LAUNCH & GUIDANCE	10/21/61	2/25/63			70.3
998-400-004	INJECTION & PARKING ORBIT INSTRUMENTATION	12/16/61	4/22/63			70.3
998-400-048	SPECIFICATIONS NOVA LAUNCH & GUIDANCE COMPL	12/16/61	4/22/63			70.3
998-400-049	CONTRACT AWARDS NOVA LAUNCH & GUIDANCE	3/10/62	7/15/63			70.3
998-400-052	COMMAND SYSTEM	1/11/64	5/17/65			70.3

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
98-400-053	TELEMETRY SYSTEMS	1/11/64	5/17/65			70.3
998-400-054	GUIDANCE SYSTEM	1/11/64	5/17/65			70.3
998-400-064	SUB-ASSEMBLY INTEGRATION END	4/04/64	8/09/65			70.3
998-400-005	2 TRACKING & TELEMETRY SHIPS	5/02/64	9/06/65			70.3
998-400-006	TRANSIT SHIP LOCATION SYSTEM	5/02/64	9/06/65			70.3
998-400-060	ABORT	5/02/64	9/06/65			70.3
998-400-061	RANGE SAFETY	5/02/64	9/06/65			70.3
998-400-007	INTEGRATION & CHECKOUT COMPLETE	5/30/64	10/04/65			70.3
998-400-062	INTEGRATION & CHECKOUT COMPLETED	5/30/64	10/04/65			70.3
998-400-055	TRACKING SUSTEMS	1/11/64	7/12/65			78.3
998-400-051	GROUND SUPPORT & CHECKOUT EQUIPMENT	1/11/64	7/12/65			78.3
998-400-056	LAUNCH AREA COMMUNICATIONS & CONTROL	2/08/64	8/09/65			78.3
998-400-057	LAUNCH STAND & BLOCK HOUSE INSTRUMENTATION	2/08/64	8/09/65			78.3
998-400-058	ELECTRONIC INTEGRATION	2/08/64	8/09/65			78.3
998-400-059	OPTICAL INTEGRATION	2/08/64	8/09/65			78.3
998-400-028	TRANSMISSION RECEPTION COMPATIBILITY	12/16/61	7/15/63			82.3
998-400-029	DATA SYSTEM DESIGN COMPLETE	1/13/62	8/12/63			82.3
998-400-030	CAPSULE XMTR SYSTEM DESIGN COMPLETED	2/10/62	9/09/63			82.3
998-400-031	DSIF GENERAL PURPOSE RECEIVER DESIGN COMPL	2/10/62	9/09/63			82.3
998-400-027	DEEP SPACE INSTRUMENTATION	3/10/62	10/07/63			82.3
998-400-067	SUB-SYSTEM TEST	3/10/62	10/07/63			82.3
998-400-020	GUIDANCE SYSTEM	11/16/63	6/14/65			82.3
998-400-024	ABORTS CHECKOUT	12/14/63	7/12/65			82.3
998-400-025	TERMINAL CHECKOUT	12/14/63	7/12/65			82.3
998-400-023	MID-COURSE MANEUVERS CHECKOUT	12/14/63	7/12/65			82.3

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
98-400-066	SUB-SYSTEM INTEGRATION COMPLETE	12/14/63	7/12/65			82.3
998-400-026	SUB-SYSTEM INTEGRATION	1/11/64	8/09/65			82.3
998-400-050	BIO-MED CONTROL	1/11/64	8/09/65			82.3
998-400-018	INTEGRATION & CHECKOUT COMPLETE	2/08/64	9/06/65			82.3
998-400-021	VOICE COMMUNICATION SYSTEM	9/21/63	6/14/65			90.3
998-400-022	TELEMETRY & DATA SYSTEM	9/21/63	6/14/65			90.3
998-400-019	GROUND XMTR & COMMAND	9/21/63	6/14/65			90.3
998-400-014	DSIE AUTOMATIC ACQUISITION SYSTEM	9/21/63	6/14/65			90.3
998-400-016	TELEVISION SYSTEM	10/19/63	7/12/65			90.3
998-400-017	SUB-SYSTEM INTEGRATION	11/16/63	8/09/65			90.3
998-400-045	3 TELEMETRY SHIPS & RECOVERY BASES	11/16/63	9/06/65			94.3
998-400-015	DEVELOP RANGING TRANS PONDER	9/21/63	8/09/65			98.3
998-400-008	FACILITY AUGMENTATION	5/05/62	4/20/64			102.3
998-400-011	HYDRAULICS SERVOS & DATA SYSTEM	6/01/63	5/17/65			102.3
998-400-012	RECEIVING RECORDING & COMMUNICATION SYSTEMS	6/29/63	6/14/65			102.3
998-400-009	THREE 85 FOOT ANTENNAS	7/27/63	7/12/65			102.3
998-400-013	SUB-SYSTEM INTEGRATION	8/24/63	8/09/65			102.3
998-400-010	CONTROL AND ADDITIONAL BUILDINGS	4/06/63	7/12/65			118.3

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

SMS SYSTEM

DATE 6/01/61 WEEK 126.1 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
998-500-043	STG 3-MAN CENTRIFUGE START CRITERIA STUDIES	6/08/61	6/29/61			3.1
998-500-025	STG S/C TRNR & FLT SIM START CRITERIA STUD	6/08/61	6/29/61			3.1
998-500-013	LRC MICRO PART ACCEL START CRITERIA STUDIES	6/08/61	6/29/61			3.1
998-500-001	LANGLEY SENSOR LAB START CRITERIA STUDIES	6/08/61	6/29/61			3.1
998-500-133	PROJECT GO-AHEAD	6/08/61	6/29/61	7/01/61		3.1
998-500-127	LEWIS LUN LNDG SIM START DESIGN CRITERIA	6/08/61	6/29/61			3.1
998-500-115	LRC HIENERGY ACCEL START CRITERIA STUDIES	6/08/61	6/29/61			3.1
998-500-109	LUN ENVIR SIMUL ULV START CRITERIA STUDIES	6/08/61	6/29/61			3.1
998-500-097	BIOTECH & BEHAV LABS START CRITERIA STUDIES	6/08/61	6/29/61			3.1
998-500-091	STG DATA PROCESSING START DESIGN STUDIES	6/08/61	6/29/61			3.1
998-500-085	STG STERILIZATION LAB START CRITERIA STUDY	6/08/61	6/29/61			3.1
998-500-055	JPL-STG 150000 LB SHAKERS START CRITERIA STUD	6/08/61	6/29/61			3.1
998-500-014	LRC MICRO PART ACCEL START DESIGN	7/06/61	7/27/61			3.1
998-500-002	LANGLEY SENSOR LAB START DESIGN	7/06/61	7/27/61			3.1
998-500-128	LEWIS LUN LNDG SIM START DESIGN	7/06/61	7/27/61			3.1
998-500-110	LUN ENVIR SIMUL ULV START DESIGN	7/06/61	7/27/61			3.1
998-500-098	BIOTECH & BEHAV LABS START DESIGN	7/06/61	7/27/61			3.1
998-500-044	STG 3-MAN CENTRIFUGE START DESIGN	8/03/61	8/24/61			3.1
998-500-116	LRC HIENERGY ACCEL START DESIGN	8/03/61	8/24/61			3.1
998-500-056	JPL-STG 150000 LB SHAKERS START DESIGN	8/17/61	9/07/61			3.1
998-500-026	STG S/C TRNR & FLT SIM START DESIGN	8/31/61	9/21/61			3.1
998-500-015	LRC MICRO PART ACCEL ISSUE BID INVITATIONS	9/14/61	10/05/61			3.1
998-500-003	LANGLEY SENSOR LAB ISSUE BID INVITATIONS	9/14/61	10/05/61			3.1
998-500-129	LEWIS LUN LNDG SIM INVITE BIDS	9/14/61	10/05/61			3.1
998-500-092	STG DATA PROCESSING START DESIGN	9/28/61	10/19/61			3.1

~~CONFIDENTIAL~~

SMS SYSTEM

DATE 6/01/61 WEEK 126.1 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
998-500-086	STG STERILIZATION LAB START DESIGN	9/28/61	10/19/61			3.1
998-500-111	LUN ENVIR SIMUL ULV INVITE BIDS	10/12/61	11/02/61			3.1
998-500-099	BIOTECH & BEHAV LABS INVITE BIDS	10/26/61	11/16/61			3.1
998-500-027	STG S/C TRNR & FLT SIM ISSUE BID INVITATIONS	11/09/61	11/30/61			3.1
998-500-117	LRC HIENERGY ACCEL INVITE BIDS	11/09/61	11/30/61			3.1
998-500-016	LRC MICRO PART ACCEL AWARD CONTRACTS	11/23/61	12/14/61			3.1
998-500-004	LANGLEV SENSOR LAB AWARD CONTRACTS	11/23/61	12/14/61			3.1
998-500-130	LEWIS LUN LNDG SIM AWARD CONTRACTS	11/23/61	12/14/61			3.1
998-500-045	STG 3-MAN CENTRIFUGE ISSUE BID INVITATIONS	12/21/61	1/11/62			3.1
998-500-017	LRC MICRO PART ACCEL START CONSTRUCTION	12/21/61	1/11/62			3.1
998-500-005	LANGLEV SENSOR LAB START CONSTRUCTION	12/21/61	1/11/62			3.1
998-500-131	LEWIS LUN LNDG SIM START CONSTRUCTION	12/21/61	1/11/62			3.1
998-500-112	LUN ENVIR SIMUL ULV AWARD CONTRACTS	12/21/61	1/11/62			3.1
998-500-028	STG S/C TRNR & FLT SIM AWARD CONTRACTS	1/18/62	2/08/62			3.1
998-500-113	LUN ENVIR SIMUL ULV START CONSTRUCTION	1/18/62	2/08/62			3.1
998-500-118	LRC HIENERGY ACCEL AWARD CONTRACTS	1/18/62	2/08/62			3.1
998-500-100	BIOTECH & BEHAV LABS AWARD CONTRACTS	1/18/62	2/08/62			3.1
998-500-093	STG DATA PROCESSING INVITE BIDS	2/01/62	2/22/62			3.1
998-500-057	JPL-STG 150000 LB SHAKERS ISSUE BID INVITNS	2/01/62	2/22/62			3.1
998-500-029	STG S/C TRNR & FLT SIM START CONSTRUCTION	2/15/62	3/08/62			3.1
998-500-119	LRC HIENERGY ACCEL START CONSTRUCTION	2/15/62	3/08/62			3.1
998-500-101	BIOTECH & BEHAV LABS START CONSTRUCTION	2/15/62	3/08/62			3.1
998-500-046	STG 3-MAN CENTRIFUGE AWARD CONTRACTS	3/01/62	3/22/62			3.1
998-500-047	STG 3-MAN CENTRIFUGE START CONSTRUCTION	3/29/62	4/19/62			3.1
998-500-087	STG STERILIZATION LAB INVITE BIDS	4/12/62	5/03/62			3.1

CONFIDENTIAL

SMS SYSTEM

DATE 6/01/61 WEEK 126.1 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
998-500-094	STG DATA PROCESSING AWARD CONTRACTS	4/26/62	5/17/62			3.1
998-500-058	JPL-STG 150000 LB SHAKERS AWARD CONTRACTS	4/26/62	5/17/62			3.1
998-500-095	STG DATA PROCESSING START CONSTRUCTION	5/24/62	6/14/62			3.1
998-500-059	JPL-STG 150000 LB SHAKERS START CONSTR	6/07/62	6/28/62			3.1
998-500-088	STG STERILIZATION LAB AWARD CONTRACTS	7/05/62	7/26/62			3.1
998-500-089	STG STERILIZATION LAB START CONSTRUCTION	8/02/62	8/23/62			3.1
998-500-030	STG S/C TRNR & FLT SIM FACILITY OPERATIONAL	7/04/63	7/25/63	7/26/63		3.1
998-500-102	BIOTECH & BEHAV LABS FACILITY OPERATIONAL	7/04/63	7/25/63	7/26/63		3.1
998-500-096	STG DATA PROCESSING FACILITY OPERATIONAL	8/01/63	8/22/63	8/23/63		3.1
998-500-114	LUN ENVIR SIMUL ULV FACILITY OPERATIONAL	8/29/63	9/19/63	9/20/63		3.1
998-500-048	STG 3-MAN CENTRIFUGE FACILITY OPERATIONAL	10/24/63	11/14/63	11/15/63		3.1
998-500-018	LRC MICRO PART ACCEL FACILITY OPERATIONAL	11/07/63	11/28/63	11/29/63		3.1
998-500-060	JPL-STG 150000 LB SHAKERS FACILITY OPNL	11/07/63	11/28/63	11/29/63		3.1
998-500-006	LANGLEV SENSOR LAB FACILITY OPERATIONAL	2/13/64	3/05/64	3/06/64		3.1
998-500-132	LEWIS LUN LNDG SIM FACILITY OPERATIONAL	4/09/64	4/30/64	5/01/64		3.1
998-500-120	LRC HIENERGY ACCEL FACILITY OPERATIONAL	4/09/64	4/30/64	5/01/64		3.1
998-500-090	STG STERILIZATION LAB FACILITY OPERATIONAL	6/04/64	6/25/64	6/26/64		3.1
998-500-037	STG MANNED FLT SUPP BLD START CRITERIA STUD	6/08/61	7/01/61			3.3
998-500-031	STG EQUIP & TECH SUPP LABS START CRITERIA STUD	6/08/61	7/01/61			3.3
998-500-019	STG ENVIRON LAB START CRITERIA STUDIES	6/08/61	7/01/61			3.3
998-500-007	MSFC GYRO LAB START CRITERIA STUDIES	6/08/61	7/01/61			3.3
998-500-121	LEWIS MIDCSE NAV & CON SIM START CRITERIA STUD	6/08/61	7/01/61			3.3
998-500-103	TRAINING CENTER START CRITERIA STUDIES	6/08/61	7/01/61			3.3
998-500-073	STG JPL ASSEMBLY FACS START CRITERIA STUDIES	6/08/61	7/01/61			3.3
998-500-079	STG JPL ACOUSTIC CHAMBERS START CRITERIA STUDY	6/08/61	7/01/61			3.3

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/01/61 WEEK 126.1 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
998-500-067	JPL 10-20 SPACE SIMS START CRITERIA STUDIES	6/08/61	7/01/61			3.3
998-500-061	JPL 30X40 SPACE SIMS START CRITERIA STUDIES	6/08/61	7/01/61			3.3
998-500-049	JPL 30000 LBS SHAKERS START CRITERIA STUDIES	6/08/61	7/01/61			3.3
998-500-032	STG EQUIP & TECH SUPP LABS START DESIGN	6/29/61	7/22/61			3.3
998-500-038	STG MANNED FLT SUPP BLD START DESIGN	6/29/61	7/22/61			3.3
998-500-008	MSFC GYRO LAB START DESIGN	6/29/61	7/22/61			3.3
998-500-104	TRAINING CENTER START DESIGN	6/29/61	7/22/61			3.3
998-500-068	JPL 10-20 SPACE SIMS START DESIGN	6/29/61	7/22/61			3.3
998-500-069	JPL 10-20 SPACE SIMS ISSUE BID INVITES	6/29/61	7/22/61			3.3
998-500-062	JPL 30X40 SPACE SIMS START DESIGN	6/29/61	7/22/61			3.3
998-500-063	JPL 30X40 SPACE SIMS ISSUE BID INVITES	6/29/61	7/22/61			3.3
998-500-050	JPL 30000 LBS SHAKERS START DESIGN	6/29/61	7/22/61			3.3
998-500-051	JPL 30000 LBS SHAKERS ISSUE BID INVITATIONS	6/29/61	7/22/61			3.3
998-500-020	STG ENVIRON LAB START DESIGN	7/06/61	7/29/61			3.3
998-500-122	LEWIS MIDCSE NAV & CON SIM START DESIGN	7/06/61	7/29/61			3.3
998-500-080	STG JPL ACOUSTIC CHAMBERS START CDESIGN	7/06/61	7/29/61			3.3
998-500-074	STG JPL ASSEMBLY FACS START DESIGN	7/06/61	7/29/61			3.3
998-500-039	STG MANNED FLT SUPP BLD ISSUE BID INVITES	8/10/61	9/02/61			3.3
998-500-033	STG EQUIP & TECH SUPP LABS ISSUE BID INVITES	8/24/61	9/16/61			3.3
998-500-009	MSFC GYRO LAB ISSUE BID INVITATIONS	8/24/61	9/16/61			3.3
998-500-105	TRAINING CENTER INVITE BIDS	8/24/61	9/16/61			3.3
998-500-021	STG ENVIRON LAB ISSUE BID INVITATIONS	8/31/61	9/23/61			3.3
998-500-123	LEWIS MIDCSE NAV & CON SIM INVITE BIDS	8/31/61	9/23/61			3.3
998-500-064	JPL 30X40 SPACE SIMS AWARD CONTRACTS	9/21/61	10/14/61			3.3
998-500-070	JPL 10-20 SPACE SIMS AWARD CONTRACTS	9/21/61	10/14/61			3.3

~~CONFI~~

~~CONFIDENTIAL~~

SMS SYSTEM

DATE 6/01/61 WEEK 126.1 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
998-500-052	JPL 30000 LBS SHAKERS AWARD CONTRACTS	9/21/61	10/14/61			3.3
998-500-081	STG JPL ACOUSTIC CHAMBERS ISSUE BID INVITES	10/12/61	11/04/61			3.3
998-500-075	STG JPL ASSEMBLY FACS ISSUE BID INVITATIONS	10/12/61	11/04/61			3.3
998-500-065	JPL 30X40 SPACE SIMS START CONSTRUCTION	10/12/61	11/04/61			3.3
998-500-071	JPL 10-20 SPACE SIMS START CONSTRUCTION	10/12/61	11/04/61			3.3
998-500-053	JPL 30000 LBS SHAKERS START CONSTRUCTION	10/12/61	11/04/61			3.3
998-500-040	STG MANNED FLT SUPP BLD AWARD CONTRACTS	10/19/61	11/11/61			3.3
998-500-034	STG EQUIP & TECH SUPP LABS AWARD CONTRACTS	11/02/61	11/25/61			3.3
998-500-010	MSFC GYRO LAB AWARD CONTRACTS	11/02/61	11/25/61			3.3
998-500-106	TRAINING CENTER AWARD CONTRACTS	11/02/61	11/25/61			3.3
998-500-022	STG ENVIRON LAB AWARD CONTRACTS	11/09/61	12/02/61			3.3
998-500-124	LEWIS MIDCSE NAV & CON SIM AWARD CONTRACTS	11/09/61	12/02/61			3.3
998-500-041	STG MANNED FLT SUPP BLD START CONSTR	11/16/61	12/09/61			3.3
998-500-035	STG EQUIP & TECH SUPP LABS START CONSTR	11/30/61	12/23/61			3.3
998-500-011	MSFC GYRO LAB START CONSTRUCTION	11/30/61	12/23/61			3.3
998-500-107	TRAINING CENTER START CONSTRUCTION	11/30/61	12/23/61			3.3
998-500-023	STG ENVIRON LAB START CONSTRUCTION	12/07/61	12/30/61			3.3
998-500-125	LEWIS MIDCSE NAV & CON SIM START CONSTR	12/07/61	12/30/61			3.3
998-500-082	STG JPL ACOUSTIC CHAMBERS AWARD CONTRACTS	12/21/61	1/13/62			3.3
998-500-076	STG JPL ASSEMBLY FACS AWARD CONTRACTS	12/21/61	1/13/62			3.3
998-500-083	STG JPL ACOUSTIC CHAMBERS START CONSTRUCTION	1/18/62	2/10/62			3.3
998-500-077	STG JPL ASSEMBLY FACS START CONSTRUCTION	1/18/62	2/10/62			3.3
998-500-072	JPL 10-20 SPACE SIMS FACILITY OPERATIONAL	8/30/62	9/22/62	9/22/62		3.3
998-500-066	JPL 30X40 SPACE SIMS FACILITY OPERATIONAL	8/30/62	9/22/62	9/22/62		3.3
998-500-054	JPL 30000 LBS SHAKERS FACILITY OPERATIONAL	8/30/62	9/22/62	9/22/62		3.3

[redacted]

CONFIDENTIAL

SMS SYSTEM

DATE 6/01/61 WEEK 126.1 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
998-500-042	STG MANNED FLT SUPP BLD FACILITY OPERNL	11/01/62	11/24/62	11/24/62		3.3
998-500-084	STG JPL ACOUSTIC CHAMBERS FACILITY OPERNL	11/22/62	12/15/62	12/15/62		3.3
998-500-078	STG JPL ASSEMBLY FACS FACILITY OPERATIONAL	11/22/62	12/15/62	12/15/62		3.3
998-500-036	STG EQUIP & TECH SUPP LABS FACILITY OPERNL	12/13/62	1/05/63	1/05/63		3.3
998-500-012	MSFC GYRO LAB FACILITY OPERATIONAL	1/24/63	2/16/63	2/16/63		3.3
998-500-108	TRAINING CENTER FACILITY OPERATIONAL	1/24/63	2/16/63	2/16/63		3.3
998-500-126	LEWIS MIDCSE NAV & CON SIM FACILITY OPERNL	4/25/63	5/18/63	5/18/63		3.3
998-500-024	STG ENVIRON LAB FACILITY OPERATIONAL	5/23/63	6/15/63	6/15/63		3.3
998-500-000	NOT TITLED	0/00/00	0/00/00			120.2

[redacted]

[redacted]

I PROBLEM

II PURPOSE

III APPROACH

IV ASSUMPTIONS

V FACTS BEARING ON THE ANALYSIS

VI CONCLUSIONS

VII RECOMMENDATIONS

SYSTEMS HAZARDS ANALYSIS

AND

SAFETY DESIGN CONSIDERATIONS

FOR

HIGH THRUST SPACE VEHICLE SYSTEMS

ANNEXES

A BLAST, FRAGMENTATION AND FIREBALL

B ACOUSTICS

C NUCLEAR

D BOARD AND TECHNICAL AREA SPECIALISTS

APPENDIX C-I TO LAUNCH FACILITIES

~~CONFIDENTIAL~~

SYSTEMS HAZARDS ANALYSIS
SAFETY DESIGN CONSIDERATIONS
FOR
HIGH THRUST SPACE VEHICLE PROGRAM

PROBLEM:

The hazards associated with preflight and launch operations are blast, acoustics, deflagration, fragmentation, toxicity and ionizing radiation. The inherent severity of these hazards dictates large separation distances between uncontrolled civilian communities and controlled launch facilities. The immenent development of high thrust space vehicles, using 12 to 22 million pound thrust boosters, will impose safety, operational and support problems far exceeding those of present day systems.

PURPOSE:

a. Define the hazards associated with launching high thrust space vehicles.

b. Analyze the degree of hazards.

c. Determine the precautions necessary to prevent exposure of uncontrolled civilian communities.

d. Develop data upon which to base decisions regarding siting considerations for new launch facilities.

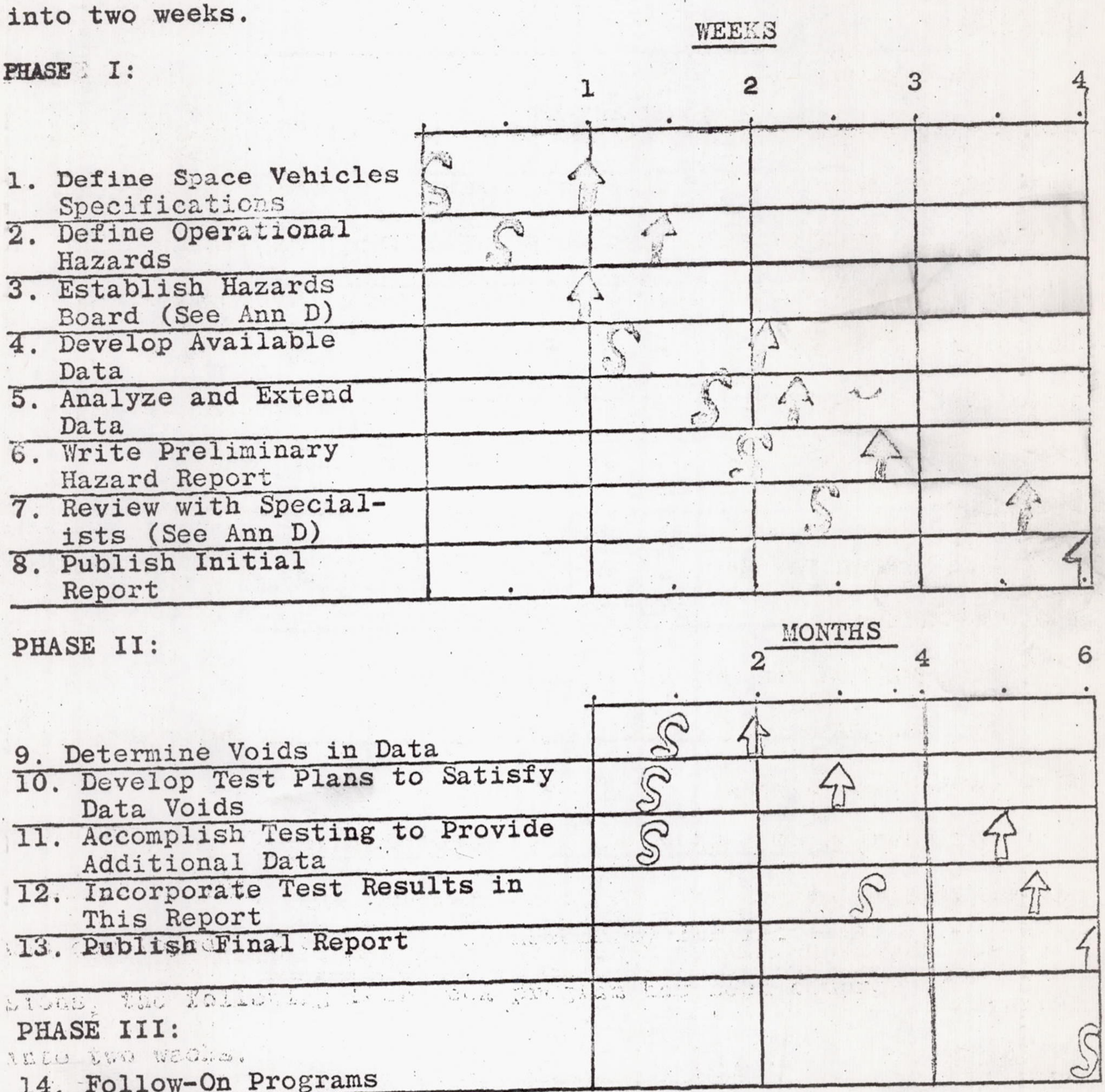
e. Establish safety limits for personnel, facilities and equipment.

APPROACH:

A Board was established consisting of representatives from Atlantic Missile Range, Space Systems Division and Marshall Space Flight Center. To carry out the objectives, the following plan

CONFIDENTIAL

was developed. Because of the necessity for immediate decisions, the following four-week program has been compressed into two weeks.



CONFIDENTIAL

CONFIDENTIAL

TABLE I OPERATIONAL HAZARDS

OPERATION	(A) BLAST Lb of TNT Eq		(B) FRAGMENTS Ft-16/Sec/Rad		(C) ACOUSTICS db(SPL)/per ft. radius		(D) DEFLAGRATION Kindling Sound/per ft/ radius		(E) RADIATION
	LIQ	SOLID	LIQ	SOLID	LIQ	SOLID	LIQ	SOLID	
A. MANUFACTURE & PROCESS	O	HU	O	HK	O	O	HK	HU	HK
B. TRANSPORT	O	O	O	HK	O	O	O	HU	HK
C. STORAGE	O	HK	O	HK	O	O	HK	HU	HK
D. ASSEMBLY	O	HU	O	HK	O	O	O	HU	HK
E. LAUNCH PAD & STATIC TEST STAND	HU	HU	HU	HK	HU	HU	HU	HU	HK
F. FLIGHT	HU	HU	HU	HK	HU	HU	HU	HU	HK
G. LAUNCH DANGER AREA	HU	HK	HU	HK	HU	HU	HU	HK	HK

KEY:

O - NO HAZARD

HU - DEGREE HAZARD UNKNOWN

HK - DEGREE HAZARD KNOWN

CONFIDENTIAL

ASSUMPTIONS:

a. The Board considered five primary high thrust space vehicle systems: (1) Saturn C3 (two F1 engines), (2) all solid, (3) a combined solid booster-liquid upper stages, (4) all liquid, and (5) liquid system with a nuclear upper stage; the third and fourth systems would be capable of launching a payload of 130,000 lbs to escape velocity. It has been calculated by NASA that this payload weight will be required to accomplish the manned lunar mission. The other assumed systems will orbit escape payload weights as shown in Figure #1.

(1) The Saturn C-3 vehicle to be developed by NASA is an all liquid system using LOX and RP-1 first stage and liquid hydrogen-liquid oxygen in all upper stages. It is a four or five stage vehicle with three million pounds of thrust in the first stage.

(2) All solid vehicle systems are assumed to be four stage segmented clustered solid propellants using ammonium perchlorate, composite propellant. The solid propellant is assumed to be a Class 2 explosive hazard with no appreciable toxic problems, based on discussions with solid propellant development agencies, who state that to accomplish the mission within the time schedule of first launch in 1964, presently available Class 2 propellants would be used. The booster is assumed to provide a maximum thrust of 22 million pounds, and provide an escape payload of 80,000 pounds. This hypothetical vehicle is provided as a guide for possible studies concerning all solid propellant vehicle systems.

(3) The combination system is assumed to use liquid upper stages and an ammonium perchlorate, composite propellant booster with a maximum thrust of 22 million pounds. Upper stages are assumed to use liquid oxygen and liquid hydrogen propellants, with which no appreciable toxic problem is associated. The assumptions concerning explosive and toxic hazards are the same as in System II.

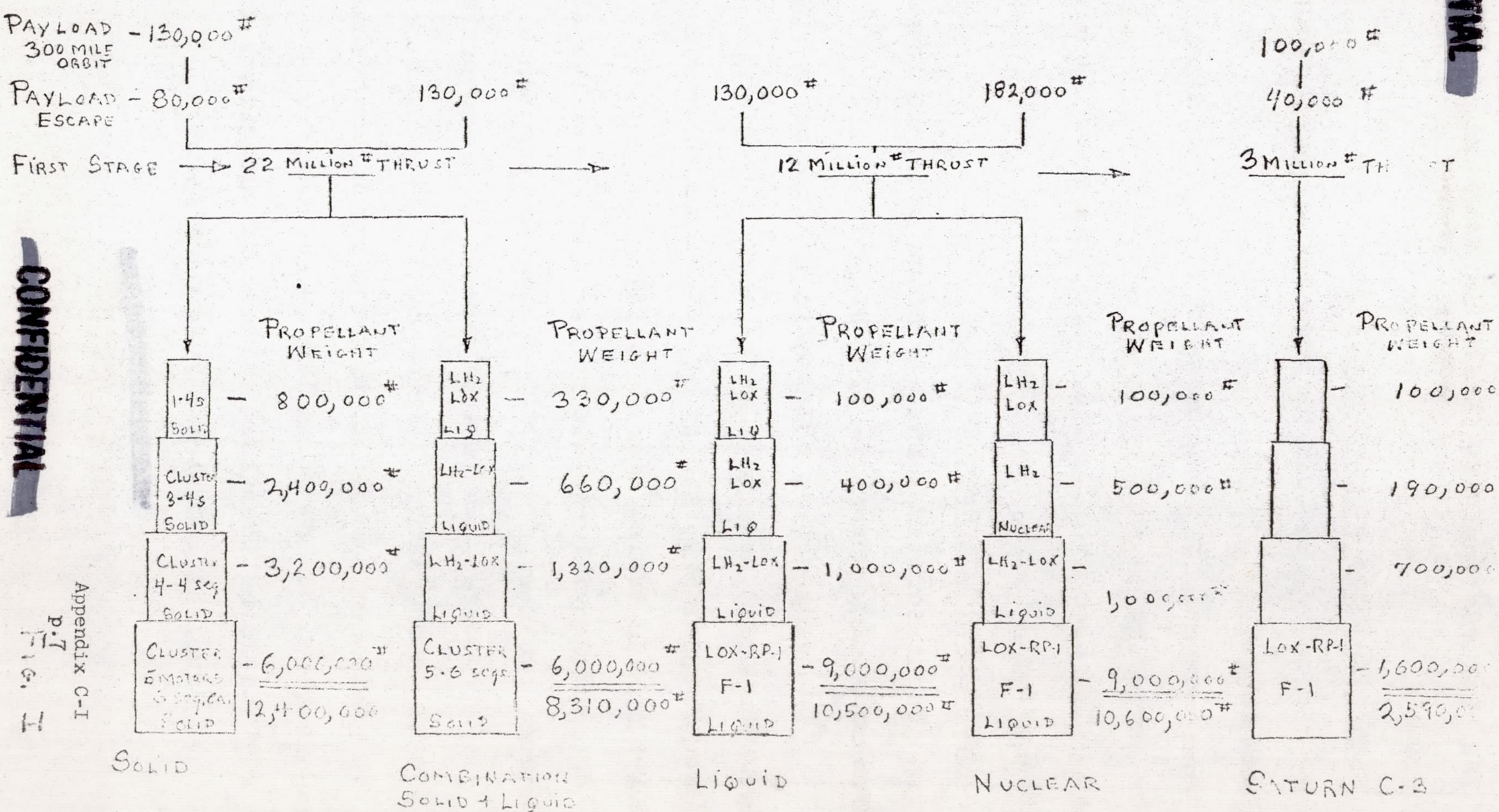
(4) All liquid vehicle systems are assumed to have four stages, the booster using liquid oxygen and RP-1 (kerosene) and the upper stages using liquid hydrogen and liquid oxygen. The booster is assumed to provide 12 million pounds of thrust from eight clustered 1.5 million pound thrust engines. There is no appreciable toxic hazard associated with the system.

(5) The system utilizing nuclear upper stage is assumed to have a 750 to 1 million pound thrust nuclear third stage with all other stages being liquid similar to System III. The first stage thrust level is assumed to be 12 million pounds.

b. See Figure 1 for detailed information regarding the assumed systems.

ASSUMED VEHICLE SYSTEMS

THESE SYSTEMS WERE DEVELOPED BY THE BOARD BECAUSE NO DEFINITE VEHICLE CONFIGURATIONS EXIST



Appendix C-I
p.7
Fig. H

FACTS BEARING ON THE ANALYSIS: CONFIDENTIAL

The "Hazards Analysis Table" is based on the following criteria:

1. BLAST (Reference Annex A):

a. Window damage can be expected at overpressures of 0.5 psi and above.

b. Conventional structures will sustain damage at pressures exceeding .5 psi.

c. The uncontrolled area limit for blast is established at 0.4 psi.

2. ACOUSTICS (Reference Annex B):

a. The theoretical maximum sound pressure level at the source of rocket motors is 170 db.

b. Measurements on the static firings of the SATURN C-1 stage, the sound pressure levels were 160 db.

c. Preliminary reading of 163 db has been recorded on the F-1 engine during static firing.

d. Tissue will sustain damage due to heating at sound pressure levels exceeding 155 db and frequencies below 200 cps.

e. Structures may sustain damage at sound pressure level of 150 db at the natural frequency of the structure.

f. Permanent damage to hearing may be sustained at sound pressure level of 150 db and frequency spectra.

g. The aural threshold of pain is recognized at the sound pressure level of 140 db and frequency spectra.

CONFIDENTIAL

h. The maximum allowable sound pressure level for personnel is established in AFR 160-3 at 135 db.

i. Blurring of the vision can occur at a sound pressure level of 130 db and 1000 to 1500 cps range; oral communication is impossible at sound pressure level of 120 db and difficult at 110 db.

j. The uncontrolled area limit, as of 1 June 1961, has been determined to be within the range of 115 to 120 db. (NOTE: All decibel readings above are SPL reference point .0002 dynes/cm^2)

3. FRAGMENTS (Reference Annex A):

a. Burning propellant from ruptured solid and liquid propellant systems will be confined to an area of 5,000 feet, based on limited available data. Fragments from similar nuclear systems will also be contained within this area, except for microscopic particles (which are discussed in Annex C).

4. DEFLAGRATION (Reference Annex A): 5 to 7 thousand degrees F. can be expected in fireball emanating from solid, nuclear or liquid mishaps. Fireball radius for all systems will be no greater than 2,000 feet.

5. RADIATION (Reference Annex C): The Basic Rules, as set down by the National Committee on Radiation Protection, (NCRP), and the International Committee on Radiological Protection (ICRP), will limit the maximum permissable exposure to ionizing radiation for both controlled and uncontrolled personnel.

CONCLUSIONS:

1. The acoustical hazard dictates the requirement for the largest amount of controlled area.

2. The controlled area must be established at the point where no real hazard will be imposed on the surrounding community.

3. Based on best engineering data available at the present time the nominal overall sound pressure levels allowable in an uncontrolled area fall within the 115-120 db (SPL) range.

4. The Hazard Analysis Chart sets forth data for the five assumed vehicles.

CONFIDENTIAL

HAZARD ANALYSIS CHART

	BOOSTER THRUST	TOTAL POUNDS PROPELLANT	ACOUSTICAL HAZARD RADII AT 115 DB (FEET)	ACOUSTICAL HAZARD RADII AT 120 DB (FEET)	TNT BLAST EQUIVALENT (KILOTONS)	0.4 PSI BLAST OVERPRESSURE RADIUS (FEET)	MAXIMUM DEFLAGRATION RADII (FEET) (FIREBALL)	MAXIMUM FRAGMENTATION HAZARD RADII (FEET)	TOXICITY HAZARDS	RADIATION HAZARDS CONTROL RADIUS (MI)
C-3 ALL LIQUID SYSTEM	3,000,000	2.59×10^6	28,000	16,000	0.377	8,640	5,000	5,000	NONE	NONE
ALL LIQUID SYSTEM *1	12,000,000	10.5×10^6	56,000	32,000	0.9	11,500	5,000	5,000	NONE	NONE
LIQUID SYSTEM W/NUCLEAR STAGE	12,000,000	10.6×10^6	56,000	32,000	1.05	12 [illegible] ~~13,750~~	5,000	5,000	NONE	~10 (*2
COMBINATION SOLID BOOSTER-LIQUID STAGES	22,000,000	8.31×10^6	80,000	45,000	1.26	13,200	5,000	5,000	NONE	NONE
ALL SOLID SYSTEM *2	22,000,000	12.4×10^6	80,000	45,000	1.24	12,800	5,000	5,000	NONE	NONE

*1. The largest thrust vehicles considered for purposes of this report.

*2. Maximum credible accident for 1 million pound thrust engine. Good diffusion conditions. P[illegible] di[illegible] [illegible] conditions Radiation Hazards Control Radius may be 25 to 40 miles

Appendix C-I p.11

CONFIDENTIAL

RECOMMENDATIONS:

1. The material in the appendices should be used to back up decisions required in the interim time period.

2. The following projects are in existence and should be expedited to provide additional data.

a. Acoustics:

(1) Recommend that NASA provide this Board with the details of the acoustics program being conducted at Marshall Space Flight Center on the SATURN booster and of a similar program on the F-1 engine being tested at Edwards AFB. Edwards AFB should establish and coordinate a similar program on the large solid booster development program conducted at Aerojet, Sacramento, and at Edwards AFB. The data from the three sources should be incorporated into this report by December 1961.

(2) Recommend the Atlantic Missile Range develop and actively apply a public information program designed to mold public opinion to the acceptability of occasional high level noise nuisance. Community response must be shaped to accept the advent of nuclear rocket stages as the normal progression of launch operations on the Cape. The maximum use should be made of positive factors (growth in business, advancement of National goals and prestige, and job security) that these advances denote.

(3) A community evaluation program by the PIO and JAG

must be developed to be used in planning PIO campaigns. This evaluation must be used on a continuing basis to measure the effect of PIO campaigns to assure the maximum result. These community evaluations will quickly uncover areas of potential community action and will assist the JAG in formulating and prosecuting a defense.

b. Blast:

(1) $LOX-LH_2$:

A contractor is working on the jointly funded Air Force-NASA program to extend date on $LOX-LH_2$ blast for large vehicles. This program is expected to be completed 30 October 1961. The data developed on this program must be included in this report.

(2) Large Solid Rocket:

The Directorate of Rocket Propulsion at Edwards Air Force Base, California has been informed that data is desired on the blast potential of the large solid rocket motor. At this date, preliminary planning is to utilize any defective motors resulting from the program for blast potential tests. Funds are not programmed to provide specific test motors. It is recommended that Edwards AFB be directed to establish a blast program. Data developed in this program must then be included in this report.

3. Nuclear:

a. Detailed meteorological data should be assembled for the launch area and surrounding communities.

b. A small non-toxic tracer program should be initiated to determine air flow and stability conditions for the various general meteorological systems.

c. If large burn tests are to be conducted, the feasibility of adding small amounts of tracer, perhaps H^3, should be considered to determine cloud size and dilution under realistic conditions.

d. A more detailed and careful analysis of the maximum credible accident should be made as soon as the reactor size and operating conditions are established.

4. It is recommended that projects be established within Air Force and NASA to provide a funding source for developing and coordinating timely "operational hazards data" without the necessity of extracting resources from the R&D phases of vehicle and weapons systems development. Lack of adequate and separate funding has precluded the development of safety criteria data in time for use by planners and designers in the R&D phase of vehicle and weapons systems development.

5. It is recommended that a permanent "Operational Hazards Board" be established to plan safety criteria, develop programs, budget funds, coordinate and review "operational hazard" problems at the development, static test, and launch sites. A vigorous follow-on program to this current effort is required to determine hazards, initiate test programs, and disseminate and coordinate data among Air Force agencies and NASA. It is recommended that a member from the Atlantic Missile Range, Directorate of Rocket Propulsion and Marshall Space Flight Center be

appointed to initially constitute the Board. Personnel appointed should be actively engaged in the operational aspects of facility development and missile safety.

ANNEX B

CONFIDENTIAL

ACOUSTICS

A. INTRODUCTION:

The purpose of this section is to present a preliminary evaluation of the acoustic limitations relating to the static firings and launching of very large vehicles and to establish guidelines enabling the facility and equipment designer to provide proper facilities and equipment and to describe operating procedures for technicians to safely operate within the controlled area.

B. DEFINITION OF NOISE SOURCE:

1. Boosters - 3 booster vehicles have been assumed to be sized at 12, 16, and 22 million pounds thrust. The approximate overall sound pressure levels generated from these boosters are presented:

THRUST MILLION POUNDS	DB (OASPL) RE. .0002 DYNES/CM^2
12	170
16	171
22	173

C. DESCRIPTION OF THE ACOUSTIC PROBLEM:

1. The noise resulting from operations at a missile static firing and launch site is a factor which should be considered during the planning of future operational installations of this type. Rocket engines and motors create high levels of acoustic energy which radiate outward into the surrounding areas during test operations. In addition to being a factor requiring consideration for personnel protection in areas very close to the

CONFIDENTIAL

source, such noise can be a source of annoyance to both on-base and off-base community residents. Thus, it becomes important and very desirable that, prior to the establishment of a given missile test installation, an estimate be made of the noise environment and subsequent community response resulting from the intended operations at this proprosed site. Unfortunately, such estimates are very difficult to make with any high degree of accuracy. There are many variables involved: the characteristics of the noise source; the nature of sound propagation through the atmosphere; and the subjective aspects pertaining to relating the stimulus to the response of the community.

2. A large amount of information currently exists in most of these problem areas resulting in engineering-type procedures for estimating the sound pressure level (SPL in db re. .0002 dynes/cm^2)-time environments produced and of the probable degree of response of communities surrounding proposed missile site operations. The validity, however, of applying existing information, much of which has been collected regarding community response to air base operations, to multi-million pound thrust rocket booster operations is questionable. Nevertheless, a "best estimate" can be made of the noise environments produced at CCMTA, both within the facility itself and in the uncontrolled area. These noise levels can be interpreted with respect to personnel damage risk, speech communication, need for protective gear, etc.

CONFIDENTIAL

3. One of the greatest uncertainties in the problem lies in relative community annoyance response to stimulus (Reference Appendix 3). The spectral content of the noise and its time history at the point in question must be considered along with the frequency and time of day or night operations. Subjection factors, such as public relations efforts, degree of dependence of the community populace on the facility, and previous exposure of the community to noise must also be considered.

4. Another important but uncertain factor is the judgement of atmospheric effect on long range propogation of the sound energy from the source to the area in question. Day by day variation in wind velocity gradients, temperature gradients, humidity, etc. result in rather large variations in sound pressure levels received at points several miles from the source. Although much work has been done by investigators on sound propogation, the range or distance of propogation under study have been limited because of lower power sound sources (i.e. aircraft) than under consideration with high thrust boosters. Yet, recognizing these limitations, long range propogation effects can be estimated.

5. The basic source characteristics must also be known or estimated; i.e., acoustic power output spectrum ; directivity indices and near field SPL distributions. Factors which influence these characteristics include effects of blast defectors and water injection in exhaust flow while the vehicle is on the pad.

CONFIDENTIAL

(Especially important in estimating environments caused by static firing operations), effects of vehicular motion while in the boost stage. The anticipated firing schedule must be known as well as the operating peramoters of the propulsion systems such as rust, weight flow, nozzle size and geometrical arrangements, etc. The extrapolation of actual sound data taken on currently available units to these very large boosters is necessarily uncertain since the acoustical efficiencies of these type noise sources will vary.

D. Method of Noise Source Determination:

1. A detailed analysis based on "best available" information as described in paragraph 2 above has not been made because of insufficient time. The estimate of environments and their effects as discussed below represent only a very cursory examination of this problem. It is recommended that the appropriate experienced personnel in this study area be utilized to obtain a more thorough analysis of the potential community noise hazards associated with future high thrust booster vehicle launch operations.

2. In spite of this fact, the sound pressure levels have been estimated by the following method:

a. For the 8 engine SATURN Booster at 100 ft from the rocket source--

$Wm = 0.673\ t^2\ g/w$ $\qquad$ $w = 608$ 16/sec

$g = 32.2$ ft/sec^2

$t = 1,500,000$ @ Isp Exp 247

$n =$ number of engines $= 8$

$W_m = 1.26 \times 10^9$ watts for one engine

$W_m^8 = 1.26 \times 10^9 \times 8 = 1.01 \times 10^{10}$ watts CONFIDENTIAL

$OAPWL = 78 + 13.5 \text{ Log. } W_m$

$OAPWL^* = 212 \text{re} 10^{-13}$ watts

$OASPL^{**} = OAPWL = 51^{***}$

$OASPL = 212 - 51$

$OASPL = 161$ db

*OAPWL = over all power level

**OASPL = over all sound pressure level

***Reference page 57 for in Air - TR - 57 - 354

b. Over all sound pressure levels can be approximated by establishing a known source, i.e., 161 db for 1.5×10^6# thrust and adding 3 db each time the power of the source is doubled. The propagation of the OASPL can also be approximated for each source of acoustic energy by subtracting 6 db each time the distance is doubled; such as 161 db OASPL exists at 100 feet for a rocket thrust of 1,500,000 pounds and at 200 feet, the approximate OASPL would be 155 db re .0002 dynes/cm^2. The inverse square line on Figure 56A, TR-57-354 also is in agreement with this extrapolation. (Reference Attachment 21.

E. ACOUSTIC CONSIDERATIONS SUMMARY:

1. Not all humans react in the same manner to noise stimulus. The reaction of people to noise of a general overall sound pressure level is a function of frequency, db level and time exposure. The results of tests performed in the vicinity of the New York Port of Authority, Idlewild Airport, indicate

the following results due to aircraft operations. (Reference Technical No. 60-4, dated July, Martin Co.).

a. OASPL of 105 db - minor complaints.

b. OASPL of 110 db - mild complaints.

c. OASPL of 115 db - severe complaints.

2. The legal aspects of noise annoyance is presented in Appendix I.

3. Physiological considerations are presented below: (See Medical Appendix 2 for further considerations)

a. Study of the relation between hearing and exposure to noise have resulted in a number of so called "damage risk criteria", which attempts to specify the maximum sound pressure levels and duration of noise exposure that may be considered safe.

b. Attachment 3, Figure 2, presents the Short Time exposure criteria for turbojet engine type noise. The maximum permissable overall sound pressure level of jet exhaust noise is given vs a function of the average daily exposure time for protected and unprotected conditions. As reflected, launch support personnel exposed to sound levels in excess of 135 db must have ear protection.

c. Blurring of vision - OASPL 135 db at 1000 to 1500 cps.

d. Threshold of pain - OASPL 135 db.

e. Permanent damage to hearing - OASPL 150 db and above.

f. Bone and tissue damage - OASPL 155 db in the 5 to 200

g. Communication cannot be carried on in an OASPL 120 db environment. It is difficult to communicate in an OASPL 110 db environment.

3. Based on the method presented in paragraph D, above, the following source radius are recommended to attenuate the sound pressure level to 115 and 120 db, respectively: (Reference Attachment 2)

BOOSTER	RADIUS REQUIRED, FT 115 db	120db
12 million lb thrust booster	55,000	32,000
16 million lb thrust booster	65,000	36,000
22 million lb thrust booster	79,000	45,000

E. RECOMMENDATIONS:

1. A complete evaluation of the acoustic problem based on available information must be initiated immediately. This work should be accomplished by angovernment agency or contract-or experienced in the acoustic field.

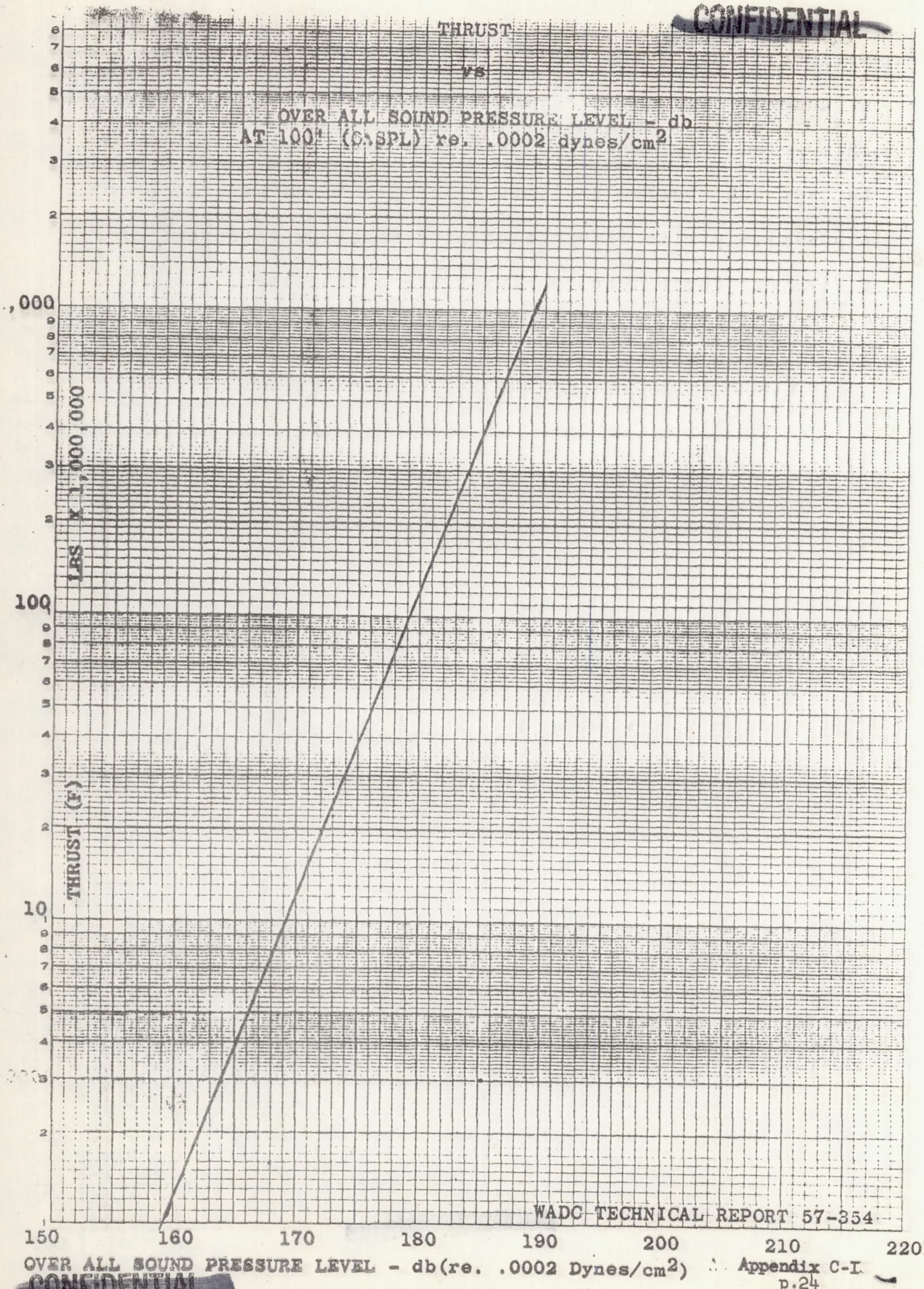
2. After review of the existing "state of the art", determine the additional experimental programs required to improve the estimate of community response to high intensity noise levels and then define acoustic criteria to be used for the launch complex.

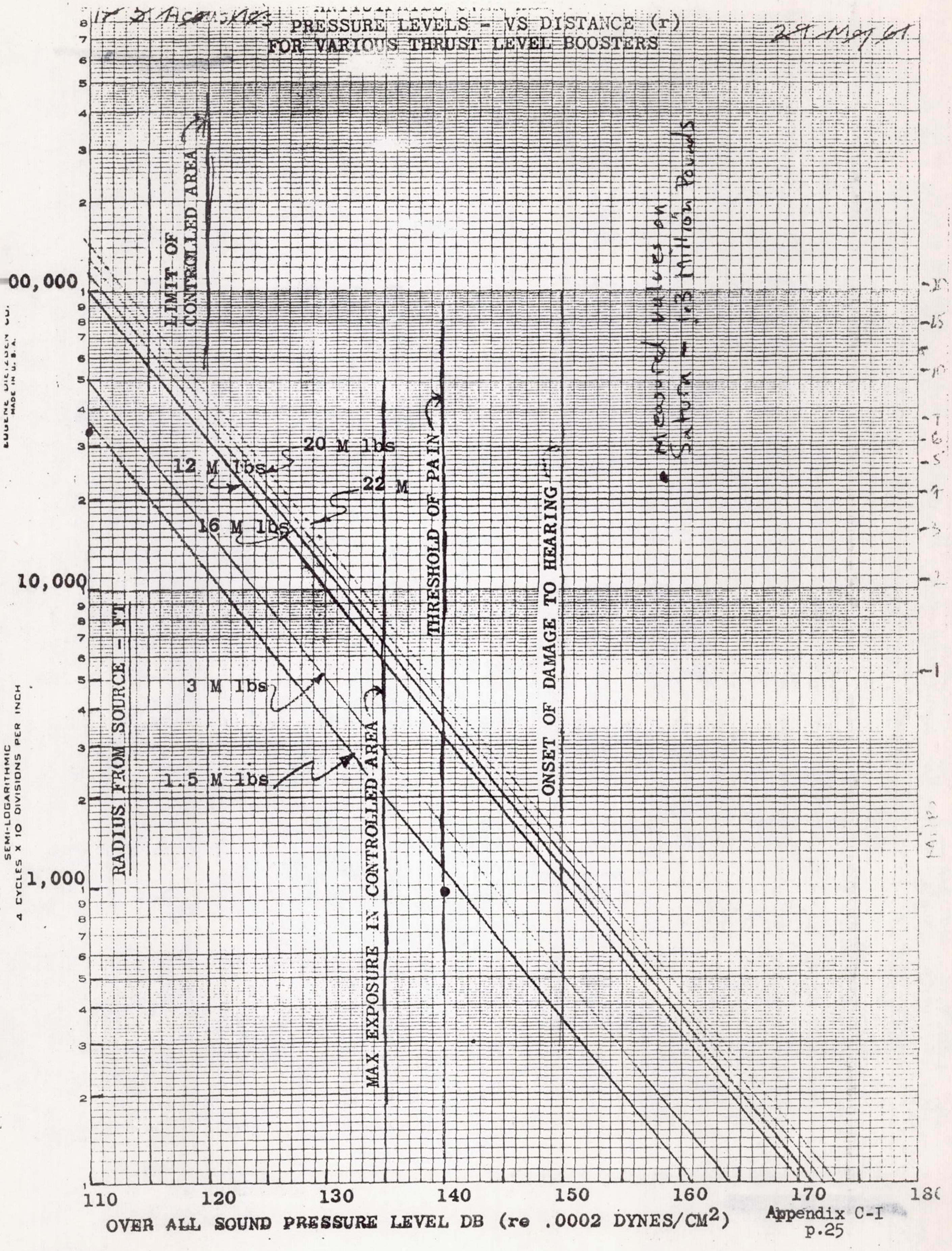
3. As larger boosters become available, continue experimental programs to further define the sonic levels and predict public response to sound stimulus.

F. CONCLUSION:

Based on best engineering data and the consideration

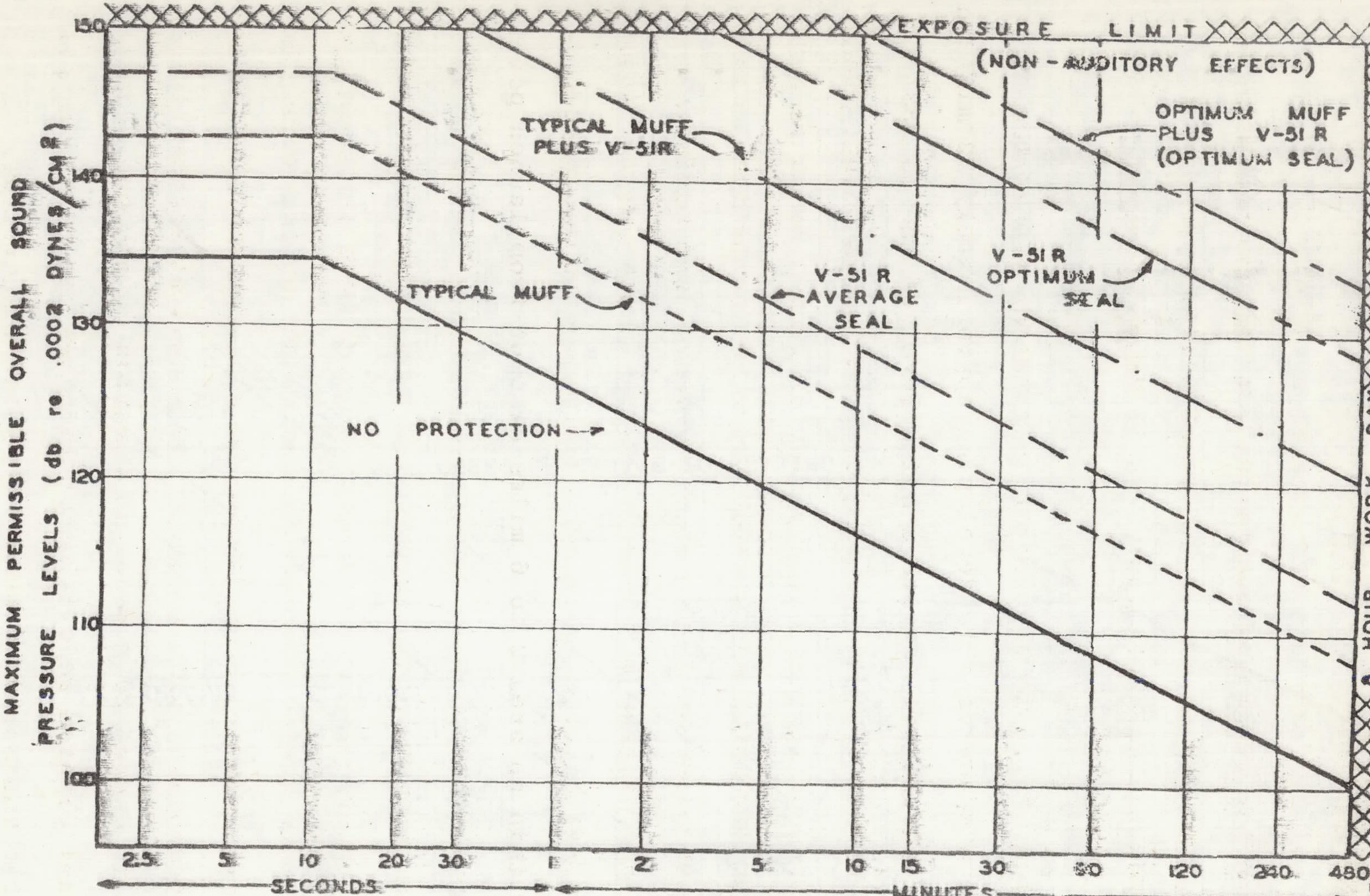
presented above, the nominal overall sound pressure level allowable in an uncontrolled area is 115 db. This allowable sound level may be increased to 120 db-SPL after further engineering analysis is complete and assurance of a positive public information program and development of a firm Air Force legal position are established.


THRUST
vs
OVER ALL SOUND PRESSURE LEVEL - db
AT 100' (OASPL) re. .0002 dynes/cm²
THRUST (F) LBS x 1,000,000
1,000
100
10
1
150
160
170
180
190
200
210
220
OVER ALL SOUND PRESSURE LEVEL - db(re. .0002 Dynes/cm²)



Appendix C-I
p.25

CONFIDENTIAL



SHORT TIME EXPOSURE CRITERIA FOR JET TYPE NOISE THE MAXIMUM PERMISSIBLE OVERALL SOUND PRESSURE LEVEL OF JET EXHAUST NOISE IS GIVEN AS A FUNCTION OF THE AVERAGE DAILY EXPOSURE TIME FOR THE PROTECTED AND UNPROTECTED EAR (FOR BASIS OF SHORT TIME EXPOSURE SEE APPENDIX.)

FIGURE 2

CONFIDENTIAL LEGAL APPENDIX I

PROBLEM

To analyze the legal problems attendant to repeated launches of space vehicles developing up to 22 million pounds of thrust from the northern most area of Cape Canaveral.

FACTS

Information available to this office indicates that the launch of a space vehicle developing approximately 22 million pounds of thrust will create a noise level of 120 to 153 decibels within a radius of 6 miles from launch point, such disturbances persisting for a period of from 3 to 20 seconds. We are further informed that the resultant noise level can be expected to cause extensive property damage and serious bodily injury within a 2 mile radius of launch point. Information is not clear as to the graduations of anticipated damage within an area 2 to 6 miles distant from launch point but it appears that serious damage and injury can occur in such area commensurate with distance from launch point. For comparison purposes noise level of 120 decibels is roughly equivalent to the sound of close by thunder or the sound that a person would hear when standing 50 feet from a rapidly moving locomotive. The frequency of such disturbances is not expected to exceed 20 seconds in duration on any one occasion, with an anticipated repetition of launches not exceeding once each week. The United States Government owns neither the proposed launch site nor the vast majority of land area which

will be inevitably affected should such launches be conducted. It becomes necessary therefore to examine the proposition of whether, aside from necessary acquisition of a suitable launch site north of the presently owned reservation at Cape Canaveral, it will be additionally necessary to acquire property rights in that area not needed for operations but affected significantly by such operations.

DISCUSSIONS

The damage which is expected to result outside the 6 mile radius (or controlled area) appears to be similar to that caused by sonic booms. Claims personnel at this base have not experienced many complaints as a result of such booms and we attribute this to the fact that the local inhabitants have accepted their role as pioneer citizens of a frontier community in the space age. Of course, if glass breakage or injury occurs as a result of the noise level the government should accept liability as it has in the instances of sonic boom claims. Normally such claims are settled administratively up to $5,000. If greater damages are sought relief must be obtained through the courts or Congress. Most missile contracts are under a cost reimbursement type of agreement under which the contractor is entitled to reimbursement for uninsured liability losses incurred in the performance of the contract. Thus, the United States Government is ultimately responsible either directly, or indirectly through reimbursement, for all claims generated by missile activities. It is

anticipated that claimants may allege that such noise creates a nuisance, trespass, or taking of property without just compensation. Generally noise is not a nuisance per se, but if it is of such character as to injure the health of ordinary persons, or unreasonably interferes with the comfort and enjoyment of private property then it may in fact be a nuisance. However, a noise level of 120 decibels for approximately 20 seconds on the average of once a week would not appear to constitute a nuisance since it would result from the Government conducting a lawful activity for the welfare of the country. Further, it does not appear that such activity would unreasonably interfere with the comfort and enjoyment of private property. Perhaps the greatest problem to be resolved is whether the noise level created is of such a character as to constitute a trespass or taking of property in violation of the Fifth Amendment to the Constitution of the United States. It has been held that if landings and take offs of an aircraft are performed at altitudes so close to private property as to interfere with its use and enjoyment it would constitute a taking without just compensation. We believe that the proposed project differs from the facts in that case since the space vehicle will not be actually flying over private property but will be at least 6 miles from it. Damages in the form of fear, anxiety, or nervousness resulting from noise or vibrations caused by planes operating nearby but not over the plaintiff's land

have been referred to as proximity damages and are generally not recoverable. Damages which are an incidental by product of lawful Government action, these are called "consequential" damages and do not constitute a taking for which compensation may be secured under the Fifth Amendment. For example, a decision by FHA to refuse mortgage insurance in areas where noise from jet planes exceeds 100 decibels will not form the basis for a compensable claim.

CONCLUSION

Taking into account the extraordinarily brief period which this office has been given to consider this complicated problem, conclusions stated herein must be wholly tentative. They are:

a. All land within a 2 mile radius of the launch point must be acquired by the Government.

b. Pending actual experience, the Government must be prepared to be deluged with claims from property owners within the 2 to 4 mile radius.

c. With respect to anticipated claims within the 2 mile to 6 mile radius each must be decided on its own merits and no generalization is now appropriate. It may be that the Government will be forced to acquire by condemnation or purchase all land areas within a 6 mile radius of launch point.

d. At the very earliest moment that such scientific data indicates that the proposed operations will constitute a "taking" land acquisition procedures should be instituted in order to minimize the staggering cost involved.

APPENDIX 2

TO

ANNEX B (ACOUSTICS)

MEDICAL

Introduction:

The nature and characteristics of the acoustic problem resulting from launchings of space vehicles powered by multi-million pounds of thrust engines (12-22 million pounds) has definite medical implications. Much research has been accomplished and results made available concerning the psychological and physiological effects of noise on man's physical well-being and performance level. *It is realized that permanent injury and even death can result from excessive noise levels and that performance effectiveness decreases with increased noise. Longer exposure time quickens the onset time and increases the detrimental effects of noise. While the setting, purpose and reliability of the numerous studies and surveys on medical effects of noise varies, all research projects agree that the medical aspects must be considered in order to achieve safe, comfortable, reliable and effective performance levels and for the maintenance of physical wellbeing and competency.

An analysis of acoustical data which large scale booster engines are expected to create reveals that the medical aspects can best be resolved by considering the controlled area as one involving an area of approximately six statute miles around the launch site. Within this area all personnel must wear ear protective devices. No person should be allowed within a mile circle of the launch site unless

housed inside the blockhouse. Until findings are obtained regarding the sound level within a blockhouse at time of launch of one of these multi-million pound thrust engines, personnel within should also wear protective ear devices.

As it is probable that windows will be broken and even structures damaged within the controlled area, people within this area must be trained and disciplined to take precautions to prevent injuries resulting from these secondary noise effects. The safest course of action would be to require all personnel to evacuate the area encompassed within the 6-mile radius at or near the launch time. At this radius, the noise level is expected to be 120 db measured in terms of over-all sound pressure level.

The uncontrolled area will extend 8.5 miles beyond the controlled area, or for a distance enclosed by a circle with a radius of 14.5 miles from the launch pad. It is estimated that the over-all sound pressure level will not exceed 115 db for more than 15-20 seconds at the extreme boundary of the 14.5 mile radius. This means that no primary medical problems are involved as the db time period stated will not cause any permanent physiological effects. Permanent or even temporary damage to farm animals is not expected, although milk spoilage and decrease in egg productivity may well result. Additional data and further analysis is required in this area.

Recommendations.

The medical problems generated by large scale boosters are not insurmountable. People can be trained to live and work in the area of concern provided certain fundamental precautions are established

and practiced. CONFIDENTIAL

1. An acoustical survey directed at determining accurately and reliably the actual noise levels, durations and frequency spectrum encountered at time of launch from distances close to the launch site to approximately 15 miles must be accomplished. This is essential to rigid definition of the acoustical areas of concern and to help specify the types of protective measures which are required.

2. Audiometric tests must be performed on all personnel engaged in missile operations to help detect anomalies and prevent suits against the Government from hearing losses incurred for other reasons. Periodic repetitions of the audiometric test will be instrumental in uncovering any latent effects, especially among people working on the large booster. Reference audiograms must be maintained.

3. The policies and procedures detailed in AFR 160-3, dated 29 October 1956, entitled "Hazardous Noise Exposure", are applicable. However, AFR 160-3 should be modified to cover circumstances involving very high noise levels (140-170 dbs) for brief periods of time.

4. All people engaged in booster operations which require that they normally work within the immediate controlled area (up to 6 miles) must wear ear protective devices at time of launch. The overall sound pressure level expected is approximately 120-160 dbs within this area. In addition, care should be taken to assure that glass breakage and plaster crumbling do not cause injuries.

5. People in the blockhouse at launch time will be within about 1,200 feet of the launch site. It is recommended that these people

also wear protective ear devices until an acoustical survey reveals that the sound level within the blockhouse during launch does not exceed 120 dbs.

6. An educational program is essential and enforcement measures must be instituted to assure that personal protective measures are established and used correctly.

PROPOSED PUBLIC INFORMATION PROGRAM

A. INTRODUCTION:

A public information program geared to prepare residents of Central Florida -- particularly those living near the Cape -- to expect missile noise levels greater than experienced in the past is necessary. The purpose of this appendix is to evaluate anticipated community reaction to the problem and to outline an information program to minimize an adverse public reaction.

B. ACHIEVING COMMUNITY ACCEPTANCE:

The economy of Brevard County, at which the AMR is located, is predicated to a large extent upon the continued existence of the Air Force Missile Test Center. Population growth closely parallels the build up of the missile test programs at AFMTC in the past decade:

County Population - 1950:	23,000
" " - 1960:	111,000

The importance of the missile program here has an almost universal acceptance. It may be assumed local residents will contend with greater personal inconveniences (e.g., high noise levels) than would be the case elsewhere.

1. Past Experience. Noise levels experienced from missile launchings in the past have been accepted by local communities as a part of day to day existence. No formal protests have ever been received by the Office of Information. The only guideline available, in which an unfavorable public reaction might have been experienced,

relates to one potential missile disaster. This occurred on 24 September 1958 when a portion of a Polaris test vehicle fell into the Banana River outside the controlled area near a crowded trailer camp. Despite the potential seriousness, the incident was accepted in a "matter of fact" manner by local communities.

2. Experience Elsewhere: To evaluate possible adverse public reaction to high noise levels, experience gained elsewhere is necessary, particularly from Huntsville and Edwards AFB. This data is not presently available. However, before development of a definitive public information program for the Cape Canaveral area, data from these localities will be evaluated.

C. PROPOSED PROGRAM:

1. A comprehensive public information program to condition local residents to increasingly greater sound levels will be developed to include:

a. Periodic releases describing results of sound studies presently underway on Atlas, Titan and Minuteman. Diagrams, drawings and elementary chart data depicting sound levels experienced with these missiles and data available on Saturn static tests will be presented in comparison form.

b. Personnel conducting acoustical studies should meet with local press representatives, describe their findings in layman's terms and extrapolate these findings to future higher thrust programs. This meeting will be properly timed so as to not alert the community to the fact that there "may be a noise problem".

c. Studies relating sound levels experienced daily to missile noises in terms of db's and duration should be made available to the Office of Information for rewrite and release.

d. Speeches by key personnel to local civic and governmental groups -- particularly in the critical Titusville area -- can augment the overall program and do much to condition the public to the problem.

2. In developing this program, a most favorable factor is that the build up to the maximum anticipated acoustical level will continue to be gradual, commencing with the Saturn C1 vehicle and progressing over a period of several years. Thus, in many respects, a community "conditioned reflex" will develop if properly guided.

3. Adverse effects such as physical and property damage must be avoided in a program of this type.

D. CONCLUSIONS:

1. A positive program of public education to increasing missile noise levels can be accomplished. However, this program must be implemented in a manner that does not lead the public to conclude there is a noise problem.

2. The possibility of undue public anxiety to high thrust vehicles at Cape Canaveral must be avoided.

3. Experience gained at other test sites is essential to supplement existing guidelines in the development of a local information program.

ANNEX C (NUCLEAR HAZARDS)

A. INTRODUCTION:

This section describes hazards associated with vehicles employing nuclear propelled stages. An attempt is made to indicate required separation distances to uncontrolled areas in the proximity of the launch site.

B. DESCRIPTION OF THE NUCLEAR HAZARDS:

1. Only those hazards associated with the launch site and the surrounding areas will be considered here.

The maximum credible accident is considered to be an excursion of the reactor caused by gross malfunction of control rods, flooding with liquid hydrogen or water, or impact which deforms the core in such a manner that it is in a critical configuration.

Impact and/or explosion of the launch vehicle is not considered to be a nuclear hazard unless it results in an excursion as described above.

C. ASSUMPTIONS:

1. It is assumed that nuclear stages will be employed only as upper stages of a launch vehicle and will not normally develop power on the launch pad except for short term operation for checkout of controls and equipment.

2. The nuclear engine will be fully assembled in the vehicle configuration; therefore, a maximum credible accident must be considered as a possibility.

[redacted]

3. The maximum physical size of the reactor will be five times as big (volume) as a KIWI-B reactor. This size was suggested by Dr. G. A. Graves (LASL)[1] as being the largest reactor he could imagine being built for this type operation. Structural problems become controlling in these large devices. A reactor of this size could develop 750,000 to 1 million pounds of thrust.

4. The maximum credible accident will consist of vaporizing 15% of the core which will make it subcritical and will be associated with 1.5×10^{21} fissions.[1]

5. Good diffusion conditions will exist when the system is fired since inversions and very stable conditions will present an unacceptable nuclear hazard downwind unless it can be guaranteed that the released materials will rise above the inversion layer. Much more detailed information will have to be available before such a guarantee can be made.

6. The maximum credible accident will be associated with a launch abort and fire. The nuclear excursion will occur in times less than 1 sec after going critical and the fission products will be released into the fire and carried in the cloud to heights of one mile. A cloud one mile deep will be formed which will then diffuse laterally as it travels with the wind.

7. The results given in LA 2409[2] can be scaled directly for this application. (It is recognized that diffusion conditions will

•

1. Private communication with Dr. G. A. Graves by Captain T. B. Kerr, 1 June 1961.

2. LA 2409, Nuclear Safety Aspects of the Rover Program. G. A. Graves, P. S. Harris, W. H. Langham, Los Alamos Scientific Laboratory, March 1960.

be different, that fission product release may not be 100%, that the maximum credible accident may not be exactly five times that assumed for KIWI-B, and that there are also uncertainties in the assumptions used for that analysis; however, no data nor proposed operations plan exists which gives reason to change these assumptions unless one is more conservative on diffusion estimates.)

8. There will be no significant blast or fireball resulting from the nuclear excursion, or if there is one, it will be small compared to that resulting from the chemical fuels.

Method of Solution and Justification for Method :

a. The solution to the nuclear hazard associated with a maximum credible accident involving a reactor capable of producing 750,000 to 1 million pounds thrust has been obtained by taking the analysis made for a similar but smaller system and scaling it to fit this system.

b. This type analysis is justified because:

1. Fission products once formed do not remember where they were formed.

2. The same meteorological conditions are assumed for both systems; therefore, downwind diffusion will be the same.

3. Better information is not available at present.

Solution:

a. External dose from maximum credible accident. Two tables are included in this appendix from which the two most significant items related to nuclear hazards can be obtained:

1. Table I gives the direct radiation doses as a function of distance for a nuclear excursion. From this, one can see that unshielded personnel at 1600 meters (1 mile) will receive 2.54 rads during an excursion and at 3200 meters (2 miles) they will receive 3.9 mrad. At distance of 10 miles where the general population are permitted, the level of radiation will be negligible.

2. Table II estimates the Beta and Gamma dose rates which will be seen as the cloud passes as a function of distance from the launch area. During the KIWI-A tests, measurements of gamma ray dose during

TABLE I. DIRECT GAMMA RAY, NEUTRON, AND TOTAL RADIATION DOSES ESTIMATED AS A FUNCTION OF DISTANCE FROM A MAXIMUM CREDIBLE ACCIDENT, 1.5×10^{21} FISSIONS, FOR UNSHIELDED PERSONNEL.

DISTANCE (meters)	DOSE RATE (rads/excursion) * Gamma Rays	Neutrons	Total
1	9×10^{8}	3.2×10^{8}	1.22×10^{9}
200	1.2×10^{4}	2.92×10^{3}	1.49×10^{4}
400	1.6×10^{3}	2.7×10^{2}	1.87×10^{3}
600	3.8×10^{2}	4.4×10^{1}	4.24×10^{2}
1000	4×10^{1}	2.2	4.22×10^{1}
1600	2.5	4.1×10^{-2}	2.54
2000	4.3×10^{-1}	3.6×10^{-3}	4.34×10^{-1}
3200	3.9×10^{-3}	3.4×10^{-6}	3.9×10^{-3}

* The above doses are for direct radiation and do not include radiation received from the fission products in the cloud as it passes.

CONFIDENTIAL

TABLE II. ESTIMATED BETA AND GAMMA RADIATION DOSE RATES IN THE CLOUD FROM A MAXIMUM CREDIBLE ACCIDENT, 1.5×10^{21} FISSIONS, AS A FUNCTION OF TIME AFTER THE EXCURSION.*

TIME POST ACCIDENT (hr)	CLOUD VOLUME (liters)	GAMMA DOSE RATE (mrads/hr)	BETA DOSE RATE (mrads/hr)
0.1	1.7×10^{13}	3.75×10^{2}	1.5×10^{3}
0.5	1.6×10^{14}	2.7×10^{1}	3.45×10^{1}
1.0 (10 miles)	4.2×10^{14}	7.2×10^{0}	5.7×10^{0}
5.0	4.2×10^{15}	9.75×10^{-2}	6.3×10^{-2}
10.0	1.4×10^{16}	1.35×10^{-2}	9×10^{-3}
24.0	4.5×10^{16}	1.65×10^{-3}	8.4×10^{-4}

* Assuming 100 per cent release of the fission products and no settling out with time.

CONFIDENTIAL

passage of the cloud gave maximum values of approximately 200 mrads at distances within one mile. The integrated power of the KIWI-A reactor was approximately 5×10^4 MW sec and it is estimated that 30 per cent of the fission products escaped. Our maximum credible accident is considered to be this same size with 100 per cent release of fission products. From this we can see that approximately 300 to 600 mrad gamma and 1500 to 3000 mrad beta will be received at 1 mile by unshielded personnel. At 2.5 miles unshielded personnel would receive 150 to 300 mrads during cloud passage and at 10 miles the general population will receive 20 or 30 mrads beta and gamma. If poor diffusion conditions exist at the time of an accident, the radiation hazard for the general population would probably be higher for a short time than normally considered acceptable at distances as great as 25 to 40 miles.

b. Internal dose from maximum credible accident -

"The approach used for assessing the internal hazard is by comparison with information on relative internal and external exposure resulting from early flight through the cloud from a nuclear detonation. Mice, monkeys and men have been flown through such clouds at times ranging from 4 minutes to an hour after detonation and the total external radiation dose measured. Estimations of internal exposure (and for the experimental animals, actual determination of absorbed fission products) showed that it was always about 1/50th or 1/100th of the external gamma exposure. The previous section showed that total gamma ray exposure during cloud passage over an area 1 mile from the source to be about 600 mrads. If the above ratio is assumed, then the internal dose under the same conditions would be 6 to 12 mrads." 2 (p 150)

c. Fallout and Area Contamination - CONFIDENTIAL

In the event of a postulated accident the fission products generated would be equivalent to approximately 0.01 KT bomb. The area immediately around the impact area would be seriously contaminated and would require considerable decontamination and clean up before it could be used again. The impact upon world-wide contamination would be very small. Such an accident would produce about 1.8 curies of Sr^{90} and 2 curies of Cs^{137}. The present rate of decrease of these two isotopes from normal decay of that produced during past bomb testing is 1.2×10^5 and 2.2×10^5 curie per year. The operation of the 1 million pound thrust reactor for 300 records at altitude or in orbit would produce approximately 240 and 260 curies of Sr^{90} and Cs^{137} which would be dispersed world-wide if released from the reactor. This again is a negligible amount compared to that presently available.

Conclusions:

The nuclear safety aspects of a maximum credible accident associated with a program for developing a nuclear propulsion system to be used as an upper stage of a multi-stage missile and which will develop up to approximately 1 million pounds thrust have been considered and the following conclusions have been reached:

1. Direct gamma rays and neutron radiation during a maximum credible accident would not produce an undue hazard to unshielded operating and launch personnel at a control center 2 miles away. Reasonable amounts of blockhouse shielding would permit reducing this distance to a few hundred yards.

2. If 100 per cent of the fission products formed were released, the radiation received (both from fallout and cloud passage) by unshielded personnel at a distance of about 2 miles or by unshielded general population groups at distances of 5 or 10 miles would not exceed presently accepted tolerances.

3. Fission product release on a test complex as a result of launch pad failure resulting in a maximum credible accident could result in local contamination that would require considerable time and decontamination prior to permanent reoccupancy of the area.

4. The addition of long lived fission products to those existing in the world as a result of past bomb testing is negligible and the contribution from a nuclear flight and/or an accident is small compared to the normal decay of existing quantities.

In addition to the above conclusions, the following additional ones are discussed in LA 2409(2).

1. Impact in a controlled area at normal re-entry with full term fission products should not constitute an unacceptable hazard for any condition of flight test. (1 KT equivalent of fission products). Impact in an uncontrolled or unknown area under the same conditions would not constitute a general hazard but could create a difficult local problem including loss of some lives and serious irradiation of others.

2. Shallow water ocean impact resulting from an aborted mission assuming 100 per cent release of fission products, could result in a contaminated body of water that would be above the usual permissible exposure levels for a few hours after impact. If fission products were

not released, the reactor would have to sink in about 15 or 20 feet of water to eliminate any radiation hazard at the surface. Deep water impact would not produce any serious or long term hazard.

3. The resulting hazard of a reactor returning to earth months or years after an orbital startup flight cannot be foreseen clearly at this time. The reactor might contain hundreds of curies which of itself would be a hazard to limited population. A reactor core remaining intact could experience an excursion and produce more fission products at impact. These problems require further consideration.

CONFIDENTIAL

ANNEX D (BOARD AND TECHNICAL AREA SPECIALISTS)

APPROVED - BOARD MEMBERS:

William H Lawrence

MR. W. H. LAWRENCE
Chief, Technical Support Division (FTRF)
Directorate of Rocket Propulsion
Space Systems Division

Louis J Ullian

MR. L. J. ULLIAN
Staff Ordnance Engineer
Missile Handling Branch (MTRSS)
Missile Operations Division
Atlantic Missile Range

R L Body

MR. R. L. BODY
AST Technical Management (M-LOD-D)
National Aeronautics and Space Administration

TECHNICAL AREA SPECIALISTS:

MR. J. MARSHALL
Chief, Equipment Development Section (FTRFE)
Directorate of Rocket Propulsion
Space Systems Division

LT COL J. J. ROSA
Bioastronautic Support Division
Staff Surgeon
Air Force Missile Test Center

MR. R. I. MAGUIRE
Chief, Solid Motor Development Branch (FTRSM)
Directorate of Rocket Propulsion
Space Systems Division

CONFIDENTIAL

CAPT T. B. KERR
Project Officer (SWRB)
AFSWC

MR. K. P. SENSTAD
Public Information Office, MTNP
AFMTC

MR. J. N. COLE
Project Engineer
Bio Acoustics Branch
Aero space Medical Lab
Aeronautical Systems Division

MR. H. G. LEISTNER
Civil Engineer
Guided Missiles Range Division (MTVRF)
Pan American World Airways

MR. JOHN KING
Public Information Office (M-PIO)
MSFC - AMR

MR. J. V. SIMMONS
Explosives Analysis Engineer
Guided Missiles Range Division (MTVRF)
Pan American World Airways

CONFIDENTIAL

PART II

SECTION D

LIFE SCIENCES PROGRAMS
FOR
EARLY MANNED LUNAR LANDING

James P. Nolan, Jr. Hq., NASA
A. H. Schwichtenberg, M. D., Lovelace Foundation

June 16, 1961

CONFIDENTIAL

THE LIFE SCIENCES

Purpose

Life Science support for the Manned Lunar Landing and Return Progam has the objectives of insuring the safety, reliability and effective performance of the flight and ground operations personnel during the preparation and conduct of the Lunar Landing mission and its necessary precursors; at the same time insuring maintenance of public health and safety.

Major Tasks (See Figure 1)

The major tasks which must be accomplished to meet the objectives are:

(1) Gathering critical medical and behavioral data on the effects of the space mission environments on men.

(2) Providing design and test criteria derived from these data, which enable development of reliable flight systems, ground support systems, and operational plans to accomplish lunar landing and return.

(3) Developing and testing special equipment in the biotechnology area needed both for the manned missions and also for the task of data gathering.

(4) Developing and implementing a personnel system plan to to insure the availability of adequate numbers of trained flight, ground operations personnel in time to conduct the missions leading up to and including manned lunar landing and return.

(5) Developing industrial medical criteria for design and operations to insure the maintenance of public health and safety.

(6) Developing and testing techniques and equipment to prevent biological and biochemical contamination of the lunar surface and conversely to prevent contamination of earth by possibly dangerous components of the lunar environment.

(7) Insuring the availability and obtaining the use of adequate trained technical personnel and research and development facilities on a national basis to accomplish the above tasks.

Problem Areas (See Figure 2)

The major technical problem areas in which life science information and technology need to be advanced in order to meet the objectives are:

(1) The biological and performance effects on man of radiations in space and the development of shielding criteria.

(2) The biological and performance effects of prolonged weightlessness.

(3) Man-machine considerations: Information display, control, work space and living space design to insure continuing effective performance of the crews, both flight and ground.

(4) The effects of combined varying psychophysiological stresses over time.

(5) Personnel systems planning including selection criteria and training methods.

(6) Life support systems integration.

(7) Bioinstrumentation.

(8) Personal protection systems.

(9) Decontamination technology.

Early Decisions and Actions (See Figure 5)

To accomplish these programs, the following critical decisions and actions are needed in the Life Science area:

(1) Initiation of Biological Radiation Satellite (BIORADS) and joint USAF-NASA Discoverer type projects.

(2) Development of Personnel Systems Plans.

(3) Decisions and agreements with other government agencies on training center sites for ground and flight crews.

(4) Initiation of design study on artifical gravity systems.

(5) Initiation of construction of lunar surface research simulator.

(6) Policy decision on decontamination of Lunar Landing Spacecraft.

Programs

To meet the Manned Lunar Landing and Return Program requirements in the noted areas, the following plan of experimentation and procedure is envisioned: (See Figure 3, Major Milestones)

1. Radiation. Radiation in space presently constitutes one of the greatest unevaluated risks to be encountered by the flight crew during the lunar mission. A radiobiological flight program is planned, which, in conjunction with the space science flight program and ground based radiobiology experiments, is designed to furnish the information required for the development of shielding and operational criteria. The space science programs will investigate the spectrum, intensities and variability of radiation fluxes in space. Radiobiological research conducted by NASA, the AEC, and in universities will provide ground based control data. The low altitude animal orbital flights, discussed under "Weightlessness" below, will provide weightless control data. A series of flight projects is planned. High altitude balloon flights will investigate the effects of heavy cosmic primaries above 130,000 feet. Biological probe flights of the BIOS (formerly NERV) series will permit investigation of the effects of 15-20 minute exposure to inner Van Allen Belt protons on lower life forms. In conjunction with the USAF, Thor-Agena launched spacecraft similar to the Discoverer series can be placed in elliptical polar orbits which will enable investigation of the effects of repeated exposure to the inner Van Allen Belt on small primates and cellular specimens for several days. It is recommended that such a program be undertaken. The most comprehensive flight experiments will be conducted in the BIORADS (Biological Radiation Satellite) project. These Atlas Agena launched spacecraft, probably modified Mercury capsules carrying up to 300 lbs. of living forms including plants, spores, microbes, rodents, monkeys and chimpanzees, are planned to be placed in para-equatorial circular orbits in the proton environment of the inner Van Allen Belt. Later BIORADS flights, launched by the Atlas-

Centaur, will be placed in para-equatorial circular orbits at 6-7000 nautical miles to investigate the effects of ambient space radiations. The effects of magnetic and electrostatic fields will also be studied. (See Figure 4)

Each of the above biological radiation flight experiments is designed to be recovered and will contain physical instrumentation to measure total dose, dose rates, spectrum, and intensity of the radiation encountered. Both telemetry and on-board recording of data will be used.

In addition, it is planned to include calibrated tissue equivalent chambers on a number of the non recoverable space science program flight experiments. The data from these will be telemetred.

2. <u>Weightlessness</u>. To determine the effects of prolonged weightlessness and the need for artificial gravity, the results of biological, medical and behavioral research on the ground and in aircraft will be compared to the results obtained from a series of orbital flight experiments. Manned flights will be preceded by successful animal flights of comparable duration. The Mercury Project and its subsequent modifications will enable recoverable flight durations of first $4\frac{1}{2}$, then 27 hours of weightlessness for animals and men and finally up to 14 days of weightlessness for animals and biological specimens. These latter flights will, in addition, provide both weightless control data for the in-flight radiobiology experiments (BIORADS) and also developmental checkout for components of advanced atmosphere and temperature control and other life support systems. Finally, in the early earth orbital flights of the lunar landing spacecraft, multi-man crews will conduct detailed in-flight medical and behavioral experiments for periods up to 14 days in order to confirm earlier results. It is during these flights that manned systems incorporating variable levels of artificial gravity may be investigated. (See Figure 4)

3. <u>Man-machine integration</u>. Ground based experimentation in simulators to determine design criteria for display and control design and location will be conducted. Design criteria for equipment maintainability will be developed. Problems arising from sensory monotony and the special requirement of preserving effective team integration in the compact and highly interdependent spacecraft environment will be investigated by prolonged isolation and restricted mobility experiments in ground

simulation equipment. Design criteria developed from these studies will be incorporated into the lunar spacecraft design and subsequently verified in earth orbital missions.

4. The Effects of Combined Psychophysiological Stresses. These will be investigated to the limit of practicability in ground simulators but final verification of man's ability to perform under such stress combinations can only be verified in the Earth Orbital Laboratory version of the lunar spacecraft.

5. The Personnel System. A plan is to be devised and implemented to assure the availability of trained flight crews and ground personnel in numbers adequate to carry out the proposed flight schedules. It will include consideration of personnel policy, selection, training and career planning as well as schedules, methods, facilities, equipment, and training personnel requirements. For some categories of individuals the training and selection lead times are comparable to those for the spacecraft and launch vehicles, and therefore this planning should commence promptly. (See Figure 4)

A very preliminary study, based on the proposed flight schedules and in part on the Project Mercury experiences, indicates that for the first group of flight crews, the initial selection process should start during the second quarter of CY 1962 and that the first group of flight crew trainees should start training in January, 1963. A second group would start training 7 months later. Exclusive of Mercury Astronauts, it was estimated that 35 to 50 persons would be needed in each of these two groups at the start of training.

It is recommended that the recruiting of civilian as well as military personnel be considered.

It is recommended that the personnel selected include individuals with special scientific skills in the areas of earth sciences, life sciences, engineering, meteorology, astronomy, as well as test pilots who meet the physical and other selection criteria.

It has been recommended that the recruiting of foreign nationals be considered.

Since the most important aspect of training involves the repetition of tasks, both mission and part-task ground based simulation equipment is to be included in the plan. Other facilities needed are launch and recovery site facilities for crew preparation, holding, and medical care.

The possibility of utilizing existing DOD facilities is very attractive from a cost and schedule standpoint and should be strongly considered. The budget plan for this report has been prepared on this premise.

Life Support System Integration and development of Bio-instrumentation are two areas in which research and development must first be conducted in ground based facilities. Checkout testing will be accomplished both in ground based environmental simulators and also in the animal and manned flight experiments.

The development and testing of Personal Protection Systems and equipment, particularly those intended for extra vehicular and lunar surface use, require the availability of a space environment and lunar surface simulation facility in which can be approximated the conditions of pressure, temperature, and radiation (other than particulate radiation) expected to be encountered. The same facility will be required for the development and testing of decontamination techniques for spacecraft, suits and lunar surface equipment. (See Figure 4)

Public Health and Safety. A joint investigation by Advanced Technology. Cape Canaveral, Life Science and U. S. Public Health Service personnel is recommended to consider the problems of noise, vibration, overpressure, fire and toxicology which may arise during the Lunar Landing Program.

MAJOR LIFE SCIENCE TASKS

1. Medical & Behavioral Data Collection
2. Human Factors Design & Test Criteria Development
3. Biotechnology Development
4. Personnel System Development
5. Public Health
6. Decontamination Technique Development

Figure 1

MAJOR LIFE SCIENCE TECHNICAL PROBLEM AREAS

1. Radiobiology and Shielding
2. Weightlessness
3. Habitability and Performance
4. Combined Stresses
5. Selection & Training Methods
6. Life Support Systems
7. Bioinstrumentation
8. Personal Protection
9. Decontamination Technology

Figure 2

MAJOR MILESTONES

LIFE SCIENCES

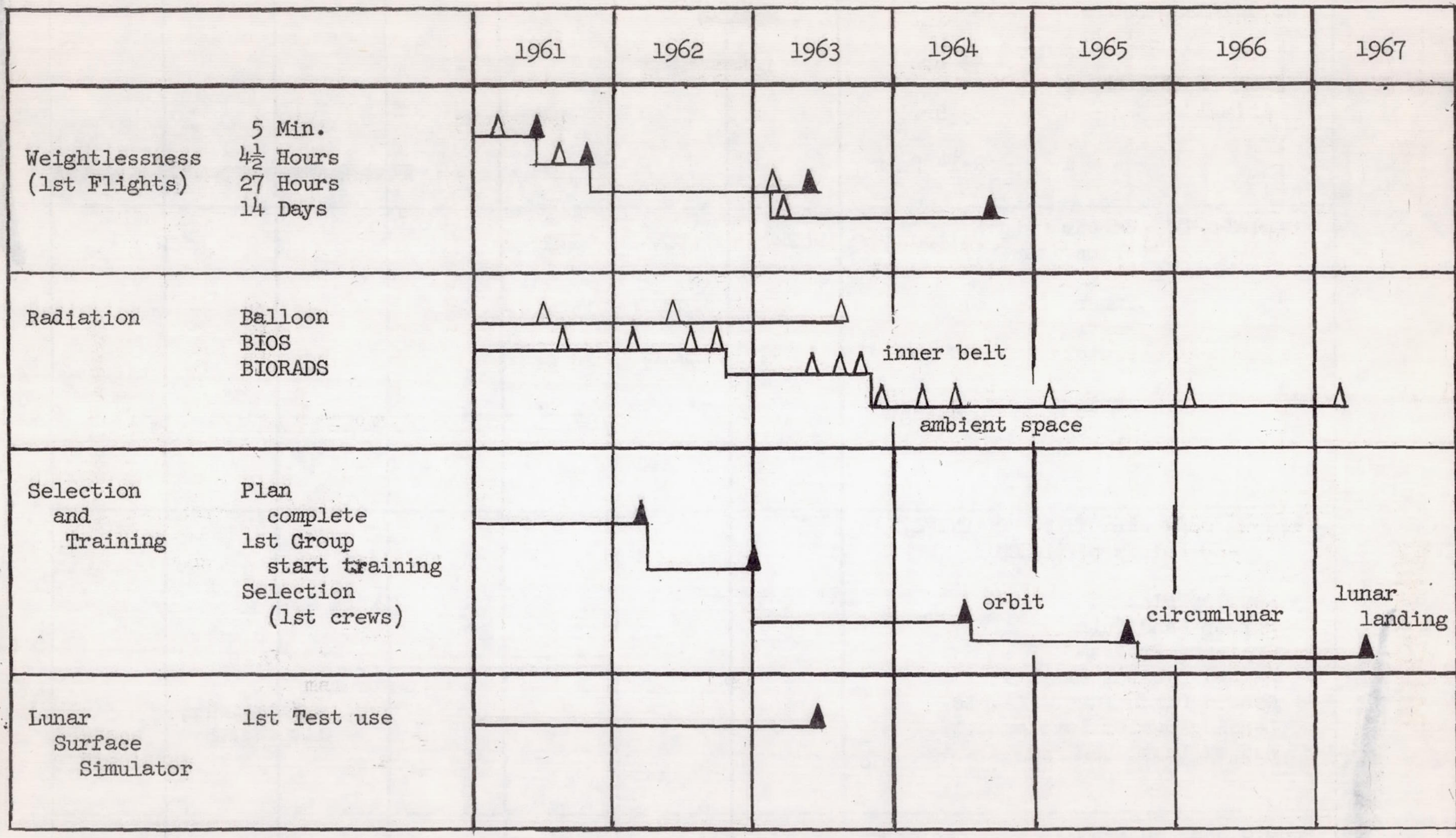


Fig. 3

△ - animal

▲ - man

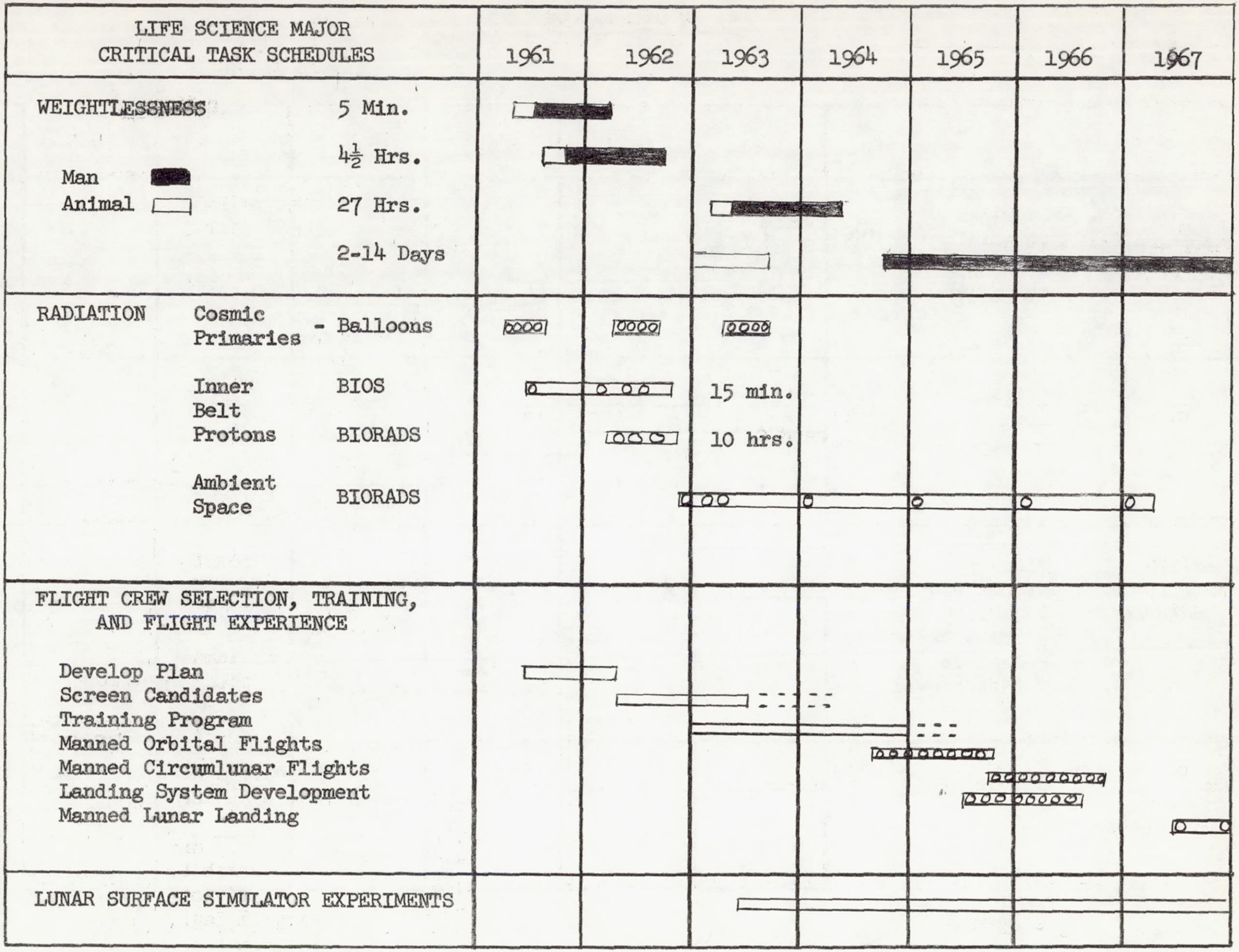

LIFE SCIENCE MAJOR
CRITICAL TASK SCHEDULES
1961
1962
1963
1964
1965
1966
1967
WEIGHTLESSNESS
5 Min.
4½ Hrs.
Man
Animal
27 Hrs.
2-14 Days
RADIATION
Cosmic Primaries
- Balloons
Inner Belt Protons
BIOS
15 min.
BIORADS
10 hrs.
Ambient Space
BIORADS
FLIGHT CREW SELECTION, TRAINING, AND FLIGHT EXPERIENCE
Develop Plan
Screen Candidates
Training Program
Manned Orbital Flights
Manned Circumlunar Flights
Landing System Development
Manned Lunar Landing
LUNAR SURFACE SIMULATOR EXPERIMENTS

Fig. 4

CRITICAL DECISIONS AND ACTIONS NEEDED

Life Sciences

1. Initiate Biorads Program
2. Develop personnel system plan and policy
3. Initiation of artificial gravity system study
4. Decision on lunar surface simulator
5. Decontamination policy decision

Fig. 5

Background and Discussion

The status of present Life Science knowledge needed for manned spaceflight is shown on Figures 6, 7, 8, and 9. These charts also show the dates at which adequate knowledge and technology in the Life Science areas to support a manned lunar landing program can be made available by the results of the experimental projects outlined. For these purposes, the manned lunar landing program is assumed to have the same requirements as a 15-day mission.

The majority of the programs outlined are either expanded versions of extant efforts or part of the NASA ten year plan. These programs are to be conducted at an accelerated rate to meet the requirements of the 1967 lunar landing goal. Information on the programs in aerospace medicine and space biology, as well as the Bios (NERV) and balloon flight projects, is available and will not be further discussed.

Three aspects of the Life Science effort have been found to be of sufficient magnitude to warrant presentation in SMS chart and computer generated table form.

Chart 55 (p. DD-1) and Table I (p. DD-2) describe the Biological Radiation Satellite Project. The milestones are representative of those which will be used when the detailed charts are drawn by the project activities. Since long term chronic radiation effects as well as acute effects will be studied on the flight specimens and particularly since genetic effects of the radiation will be studied on the progeny of the flight specimens, very carefully controlled breeding is envisioned. The time allowances for breeding, stabilization and control studies are somewhat longer than in the case

EXTENT OF KNOWLEDGE
Space Medical and Behavioral Science
1. Biophysics

Fig. 6

		Adequate for Manned Spaceflight of:										
		Hours			Days						Years	
Stressors or Limitations	Inadequate for Manned Spaceflight	1	3	10	1	3	10	15	30	100	1	3+
Temperature Limitations									60			61
Pressures and Partial Pressures (other than atmospheric)						61		62				
Relative Humidity									60			61
Accelerations												
Linear						61		62				
Angular				60	61			62				
Weightlessness		61	61		62			63				
Accelerations after Weightlessness	60	61	61		62			63				
Radiation--Particulate and Electromagnetic Spectrum												
Gonadal Dosage Effects					60			63				
Total Body Effects									60			
Illumination and Vision					60	61		62				
Air Ionization in Spacecraft							60		61			
Noise											60	
Vibration						60			63			
Effects of Combined Biophysical Stressors	60	61	61		63			64				
Fields												
Magnetic			61					63				
Electrostatic			61					63				

EXTENT OF KNOWLEDGE
Space Medical and Behavioral Science
2. Biochemistry

Fig. 7

Stressors or Limitations	Inadequate for Manned Spaceflight	Adequate for Manned Spaceflight of: Hours 1	3	10	Days 1	3	10	15	30	100	Years 1	3
Metabolism			61		62			63				
Energy Requirements			61		62			63				
Water Cycle			61		62			63				
Food-Waste Cycle			61		62			63				
Air Cycle						61		63				
Atmosphere (other than normal)						61		63				
Drugs to Increase Tolerance		61										
Toxicology												
Materials, Finishes and Processes			61					62				
Odors			61					62				
Chemicals and Fuels						60		62				
Effects of Combined Biochemical Stressors	60	61	61		63			64				

Fig. 8

Stressors or Limitations	Inadequate for Manned Spaceflight	Adequate for Manned Spaceflight of: Hours 1	Hours 3	Hours 10	Days 1	Days 3	Days 10	Days 15	Days 30	Days 100	Years 1	Years 3
Maintenance of Muscle Tone						61		63				
Physical Effort Required for Tasks						61		63				
Work-Sleep-Recreation Cycle						61		63				
Fatigue												
Physical						61		63				
Emotional					60			64				
Perception-Cognition-Response (performance)		61						63				
Disorientation			61		63			64				
Effects of Combined Psychophysiological Stressors	60	61	61		62			64				

Fig. 9

Stressors or Limitations	Inadequate for Manned Spaceflight	Adequate for Manned Spaceflight of: Hours 1	Hours 3	Hours 10	Days 1	Days 3	Days 10	Days 15	Days 30	Days 100	Years 1	Years 3
Cabin Space Requirements							61	62				
Man-Machine Relationship		61	61		63			64				
Regenerative Systems--Food and Oxygen	60											
Ground Simulation			61		62			63				
Ground Support								60				
Illness and Injury									60			
Astronaut Selection (Flight Crew Criteria)					61			62				
Operational Reliability			61		62			63				
Integration of Environmental Control Systems with Other Spacecraft Systems			61		62			63				

of the times allowed for these functions in the weightlessness experiments. The use of available chimpanzees was assumed. If new animals, which are shipped from Africa at the age of 3-4 months, are to be used, the latest allowable date for milestone 805 is about 9/15/61, rather than 6/19/62, and action would be needed upon project initiation.

Chart 53 (p. DD-6) and Table II (p. DD-7) describe the 14-day animal shots in the Earth Orbiting Recoverable Biological Satellite (modified Mercury capsule) for determination of the effects of weightlessness on various organisms. The milestones chosen in the paths which outline the preparation of the biological experiments are representative of those which must be accomplished during the course of the project. Two assumptions have been made in the preparation of Chart 53 which, if changed, would necessitate critical action. First, it is assumed that the rodent colony would be largely obtained from a contractor. If this were not done, that is, if NASA were to undertake the entire task, the latest allowable date for milestone 805 would be about 9/15/61 rather than 1/25/62. Secondly, it is assumed that chimpanzees already available at Holloman Air Force Base would be used for these experiments. If this were not the case, action to obtain these animals would be required at initiation of the project (7/1/61). More detailed information on the nature of the experiments and techniques to be used is available in the form of a PPDP.

Chart 76 (p. DD-10) and Table III describe the selection, training, and flight experience milestone sequence for the flight crews. On the basis of the assumptions listed below and the master schedule, it was found that a minimum of twelve crews was required. Figure 10 shows the time dependent

utilization of these crews. In Table III, it will be seen that the latest allowable date to start the first group of crew candidates in training is 1/10/63.

The following assumptions were used in the preparation of Chart 76 and were obtained in part from the operation and training personnel of the Space Task Group.

1. It would be attempted to meet the schedules shown on the master launch chart. The scheduled launch dates are shown on the chart under the launch blocks.

2. The vehicles would be prepared in groups of two by three crews per group, except for curcumlunar flight No. 5, which is prepared singly by two crews.

3. Vehicle preparation time, during which the crews must devote their entire schedule to vehicle checkout and flight simulation, is twelve weeks.

4. In cases in which the two vehicles of a given group are launched one or two months apart, two crews would be needed 12 weeks prior to launch of the first vehicle; the third crew need not be available until 12 weeks prior to launch of the second vehicle. In some cases where the time was available, all three crews were scheduled to start preparation of the first vehicle; however, the use of the basic assumption stated would not, in these cases, have reduced the total numbers of crews needed.

5. It is assumed that all flights scheduled would be launched, except in the case of lunar landing. In this case there are two

groups of two vehicles, the first group scheduled for launch several months prior to the second. It is assumed that only one launch would be attempted per group.

6. No individual should fly a mission more than once in 6 months. (The total number of crews required for the project is relatively insensitive to reduction in this number.)

7. Three astronauts would be available from the Mercury Program for this flight series, and would require a 6-months project familiarization time prior to starting a launch preparation.

8. Other flight crew members would require a one year period for preflight, academic cross-training and dynamic stress testing followed by a 6-months familiarization period prior to starting a launch preparation. No detailed assumptions about the syllabus are involved.

9. The selection sequence is somewhat similar to Mercury. No assumptions of breadth and depth other than those apparent on the chart are made.

10. The crew matching blocks (#524 and #526) represent tentative matching only. Flexibility to interchange crew members, at least within a group of three crews preparing a set of two launches, is retained.

11. No assumptions regarding the number of personnel per crew was required to prepare this chart, except that all flights would be manned by the same number of people.

12. The development drop tests shown on the master chart would be manned by personnel other than these flight crews. However, drop tests for training might be scheduled (but not necessarily) during the launch preparation phase.

13. The 3-orbit and 18-orbit Mercury shots would be manned by the existing group of astronauts.

14. After start of preparation, none of the crews is available for other duties until after launch.

15. No allowance was made for post training attrition prior to 5/1/66. (See also Figure 10)

16. No assumptions regarding attrition during the preflight training periods were necessary to prepare the chart.

Several additional references were consulted to determine the degree of optimism or conservatism inherent in the above assumptions. Two of these are worthy of mention:

1. Project Horizon, Phase I Report, "A U.S. Army Study for the Establishment of a Lunar Military Outpost," Vol III, 8 June 1959 (SECRET).

2. "ADVANCED DESIGN TRAINER," USAF SR49756, AST-EOR-12976, June 1960, Vought Astronautics Div., Chance Vought Aircraft. (SECRET)

The concensus of the references consulted pertaining to somewhat similar training programs was that one could expect about 30% attrition during preflight training and a cumulative attrition of 30% to 50% during the post training flight phases. It has also been estimated that for certain space missions,

four to six fully qualified crews should be available at launch for each crew actually flown. The references should be investigated more closely before a final plan is drawn.

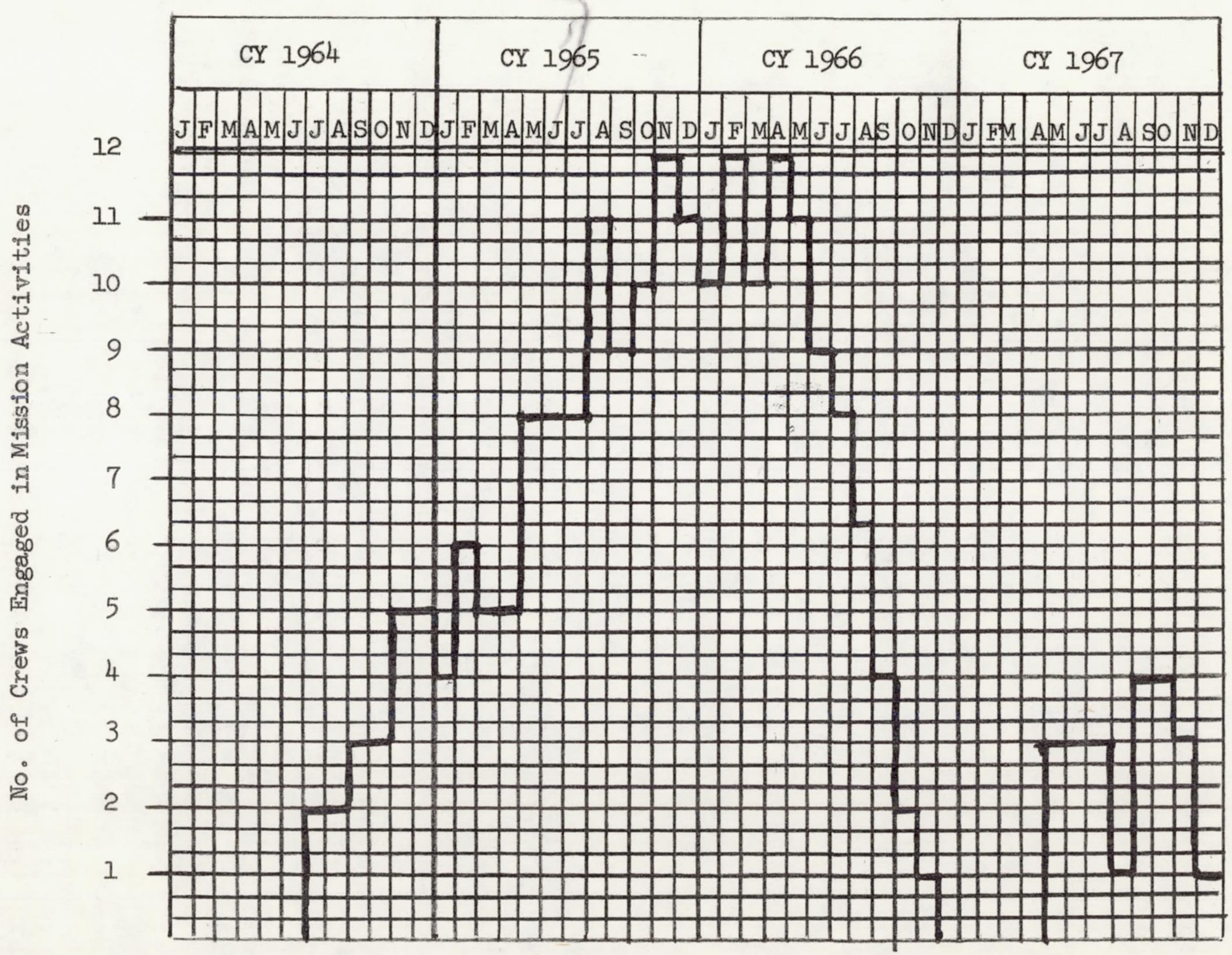

CY 1964
CY 1965
CY 1966
CY 1967
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
12
11
10
9
8
7
6
5
4
3
2
1
No. of Crews Engaged in Mission Activities

Fig. 10

CONFIDENTIAL

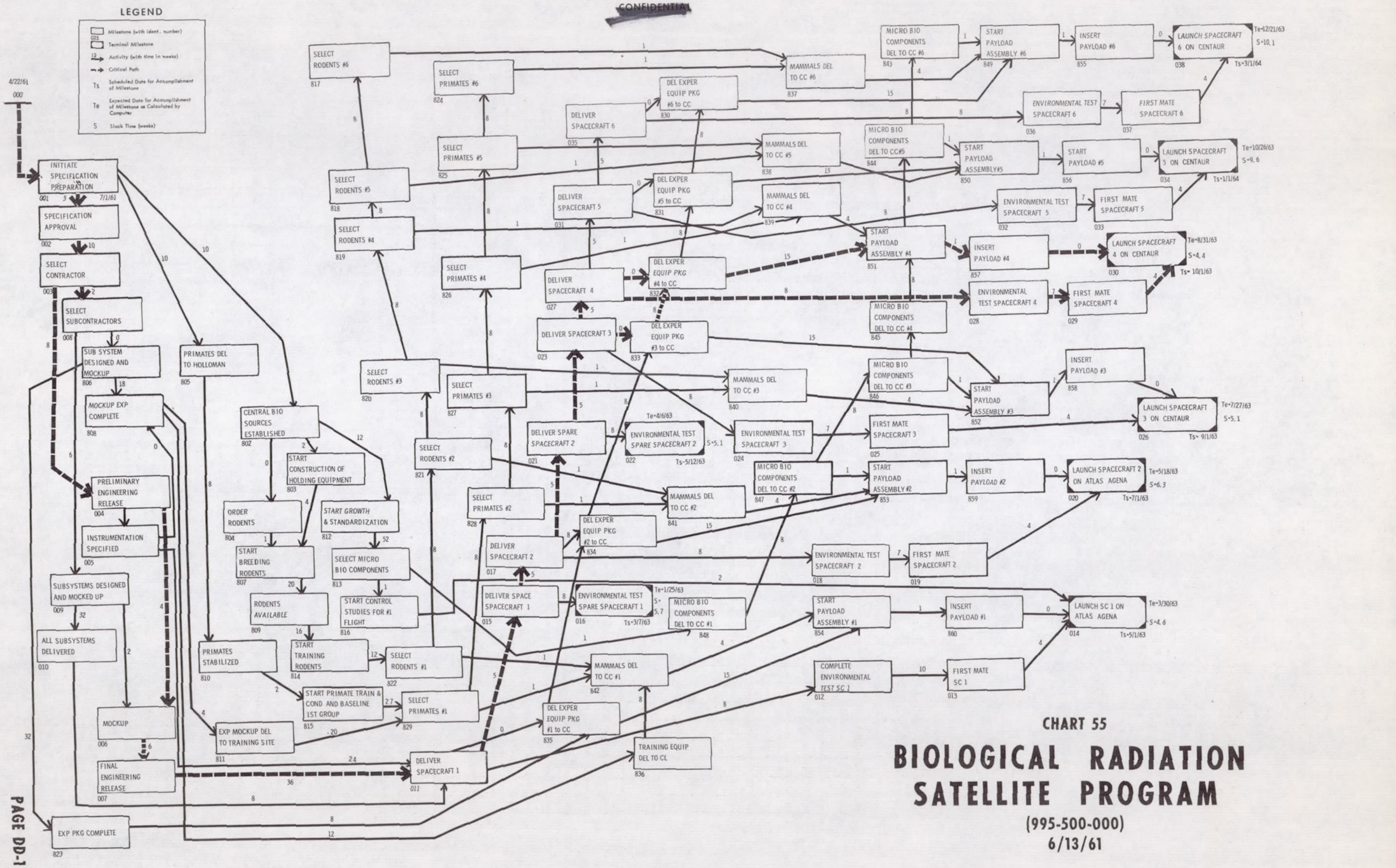


CHART 55

BIOLOGICAL RADIATION SATELLITE PROGRAM

(995-500-000)
6/13/61

CONFIDENTIAL

SMS SYSTEM

DATE 6/09/61 WEEK 127.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-500-000	START	0/00/00	0/00/00			4.4
995-500-001	INITIATE SPECIFICATION PREPARATION	7/01/61	8/01/61	7/01/61		4.4
995-500-002	SPECIFICATION APPROVAL	8/05/61	9/05/61			4.4
995-500-003	SELECT CONTRACTOR	10/14/61	11/14/61			4.4
995-500-004	PRELIMINARY ENGINEERING RELEASE	12/09/61	1/09/62			4.4
995-500-006	MOCKUP	1/06/62	2/06/62			4.4
995-500-007	FINAL ENGINEERING RELEASE	2/17/62	3/20/62			4.4
995-500-011	DELIVER SPACECRAFT 1	10/27/62	11/27/62			4.4
995-500-015	DELIVER SPARE SPACECRAFT 1	12/01/62	1/01/63			4.4
995-500-017	DELIVER SPACECRAFT 2	1/05/63	2/05/63			4.4
995-500-021	DELIVER SPARE SPACECRAFT 2	2/09/63	3/12/63			4.4
995-500-023	DELIVER SPACECRAFT 3	3/16/63	4/16/63			4.4
995-500-833	DEL EXPER EQUIP PKG 3 TO CC	3/16/63	4/16/63			4.4
995-500-027	DELIVER SPACECRAFT 4	4/20/63	5/21/63			4.4
995-500-832	DEL EXPER EQUIP PKG 4 TO CC	5/11/63	6/11/63			4.4
995-500-028	ENVIRONMENTAL TEST SPACECRAFT 4	6/15/63	7/16/63			4.4
995-500-029	FIRST MATE SPACECRAFT 4	8/03/63	9/03/63			4.4
995-500-851	START PAYLOAD ASSEMBLY 4	8/24/63	9/24/63			4.4
995-500-030	LAUNCH SPACECRAFT 4 ON CENTAUR	8/31/63	10/01/63	10/01/63		4.4
995-500-857	INSERT PAYLOAD 4	8/31/63	10/01/63			4.4
995-500-012	COMPLETE ENVIRONMENTAL TEST SC 1	12/22/62	1/23/63			4.6
995-500-013	FIRST MATE SC 1	3/02/63	4/03/63			4.6
995-500-014	LAUNCH SC 1 ON ATLAS AGENA	3/30/63	5/01/63	5/01/63		4.6
995-500-022	ENVIRONMENTAL TEST SPARE SPACECRAFT 2	4/06/63	5/12/63	5/12/63		5.1
995-500-024	ENVIRONMENTAL TEST SPACECRAFT 3	5/11/63	6/15/63			5.1

CONFIDENTIAL

SMS SYSTEM

DATE 6/09/61 WEEK 127.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-500-025	FIRST MATE SPACECRAFT 3	6/29/63	8/04/63			5.1
995-500-026	LAUNCH SPACECRAFT 3 ON CENTAUR	7/27/63	9/01/63	9/01/63		5.1
995-500-016	ENVIRONMENTAL TEST SPARE SPACECRAFT 1	1/26/63	3/07/63	3/07/63		5.7
995-500-018	ENVIRONMENTAL TEST SPACECRAFT 2	3/02/63	4/15/63			6.3
995-500-019	FIRST MATE SPACECRAFT 2	4/20/63	6/03/63			6.3
995-500-020	LAUNCH SPACECRAFT 2 ON ATLAS AGENA	5/18/63	7/01/63	7/01/63		6.3
995-500-008	SELECT SUBCONTRACTORS	10/28/61	12/12/61			6.4
995-500-009	SUBSYSTEMS DESIGNED & MOCKED UP	12/09/61	1/23/62			6.4
995-500-834	DEL EXPER EQUIP PKG 2 TO CC	1/05/63	2/19/63			6.4
995-500-852	START PAYLOAD ASSEMBLY 3	6/29/63	8/24/63			8.1
995-500-858	INSERT PAYLOAD 3	7/06/63	9/01/63			8.1
995-500-835	DEL EXPER EQUIP PKG 1 TO CC	10/27/62	12/25/62			8.4
995-500-853	START PAYLOAD ASSEMBLY 2	4/20/63	6/24/63			9.3
995-500-859	INSERT PAYLOAD 2	4/27/63	7/01/63			9.3
995-500-831	DEL EXPER EQUIP PKG 5 TO CC	7/06/63	9/11/63			9.6
995-500-850	START PAYLOAD ASSEMBLY 5	10/19/63	12/25/63			9.6
995-500-034	LAUNCH SPACECRAFT 5 ON CENTAUR	10/26/63	1/01/64	1/01/64		9.6
995-500-856	INSERT PAYLOAD 5	10/26/63	1/01/64			9.6
995-500-830	DEL EXPER EQUIP PKG 6 TO CC	8/31/63	11/09/63			10.1
995-500-849	START PAYLOAD ASSEMBLY 6	12/14/63	2/22/64			10.1
995-500-038	LAUNCH SPACECRAFT 6 ON CENTAUR	12/21/63	3/01/64	3/01/64		10.1
995-500-855	INSERT PAYLOAD 6	12/21/63	3/01/64			10.1
995-500-010	ALL SUBSYSTEMS DELIVERED	7/21/62	10/02/62			10.4
995-500-854	START PAYLOAD ASSEMBLY 1	2/09/63	4/24/63			10.6
995-500-860	INSERT PAYLOAD 1	2/16/63	5/01/63			10.6

CONFIDENTIAL

Table I

CONFIDENTIAL

SMS SYSTEM

DATE 6/09/61 WEEK 127.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-500-031	DELIVER SPACECRAFT 5	5/25/63	8/21/63			12.6
995-500-032	ENVIRONMENTAL TEST SPACECRAFT 5	7/20/63	10/16/63			12.6
995-500-033	FIRST MATE SPACECRAFT 5	9/07/63	12/04/63			12.6
995-500-005	INSTRUMENTATION SPECIFIED	3/03/62	6/12/62			14.4
995-500-035	DELIVER SPACECRAFT 6	6/29/63	10/19/63			16.1
995-500-036	ENVIRONMENTAL TEST SPACECRAFT 6	8/24/63	12/14/63			16.1
995-500-037	FIRST MATE SPACECRAFT 6	10/12/63	2/02/64			16.1
995-500-802	CENTRAL BIO SOURCES ESTABLISHED	9/09/61	1/02/62			16.4
995-500-812	START GROWTH AND STANDARDIZATION	12/02/61	3/27/62			16.4
995-500-813	SELECT MICRO BIO COMPONENTS	12/01/62	3/26/63			16.4
995-500-848	MICRO BIO COMPONENTS DEL TO CC 1	12/08/62	4/02/63			16.4
995-500-847	MICRO BIO COMPONENTS DEL TO CC 2	2/02/63	5/28/63			16.4
995-500-846	MICRO BIO COMPONENTS DEL TO CC 3	3/30/63	7/23/63			16.4
995-500-845	MICRO BIO COMPONENTS DEL TO CC 4	5/25/63	9/17/63			16.4
995-500-816	START CONTROL STUDIES FOR 1 FLIGHT	12/08/62	4/17/63			18.6
995-500-806	SUB SYSTEM DESIGNED AND MOCKUP	10/28/61	3/20/62			20.4
995-500-823	EXP PACKAGE COMPLETE	6/09/62	10/30/62			20.4
995-500-844	MICRO BIO COMPONENTS DEL TO CC 5	7/20/63	12/18/63			21.6
995-500-843	MICRO BIO COMPONENTS DEL TO CC 6	9/14/63	2/15/64			22.1
995-500-803	START CONSTRUCTION OF HOLDING EQUIPMENT	9/23/61	3/06/62			23.4
995-500-807	START BREEDING RODENTS	10/21/61	4/03/62			23.4
995-500-809	RODENTS AVAILABLE	3/10/62	8/21/62			23.4
995-500-814	START TRAINING RODENTS	6/30/62	12/11/62			23.4
995-500-822	SELECT RODENTS 1	9/22/62	3/05/63			23.4
995-500-821	SELECT RODENTS 2	11/17/62	4/30/63			23.4

CONFIDENTIAL

Table II

CONFIDENTIAL

SMS SYSTEM

DATE 6/09/61 WEEK 127.2 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-500-820	SELECT RODENTS 3	1/12/63	6/25/63			23.4
995-500-819	SELECT RODENTS 4	3/09/63	8/20/63			23.4
995-500-839	MAMMALS DEL TO CC 4	3/16/63	8/27/63			23.4
995-500-842	MAMMALS DEL TO CC 1	9/29/62	3/27/63			25.6
995-500-841	MAMMALS DEL TO CC 2	11/24/62	5/27/63			26.3
995-500-840	MAMMALS DEL TO CC 3	1/19/63	7/27/63			27.1
995-500-804	ORDER RODENTS	9/09/61	3/27/62			28.4
995-500-808	EXP MOCKUP COMPLETE	3/03/62	9/18/62			28.4
995-500-811	EXP MOCKUP DEL TO TRAINING SITE	3/31/62	10/16/62			28.4
995-500-829	SELECT PRIMATES 1	8/18/62	3/05/63			28.4
995-500-828	SELECT PRIMATES 2	10/13/62	4/30/63			28.4
995-500-827	SELECT PRIMATES 3	12/08/62	6/25/63			28.4
995-500-826	SELECT PRIMATES 4	2/02/63	8/20/63			28.4
995-500-818	SELECT RODENTS 5	5/04/63	11/20/63			28.6
995-500-838	MAMMALS DEL TO CC 5	5/11/63	11/27/63			28.6
995-500-817	SELECT RODENTS 6	6/29/63	1/18/64			29.1
995-500-837	MAMMALS DEL TO CC 6	7/06/63	1/25/64			29.1
995-500-825	SELECT PRIMATES 5	3/30/63	11/20/63			33.6
995-500-824	SELECT PRIMATES 6	5/25/63	1/18/64			34.1
995-500-836	TRAINGING EQUIP DEL TO CC	5/26/62	1/30/63			35.6
995-500-805	PRIMATES DEL TO HOLLOMAN	9/09/61	6/19/62			40.4
995-500-810	PRIMATES STABILIZED	11/04/61	8/14/62			40.4
995-500-815	START PRIMATE TRAIN AND COND AND BASELINE	11/18/61	8/28/62			40.4

6

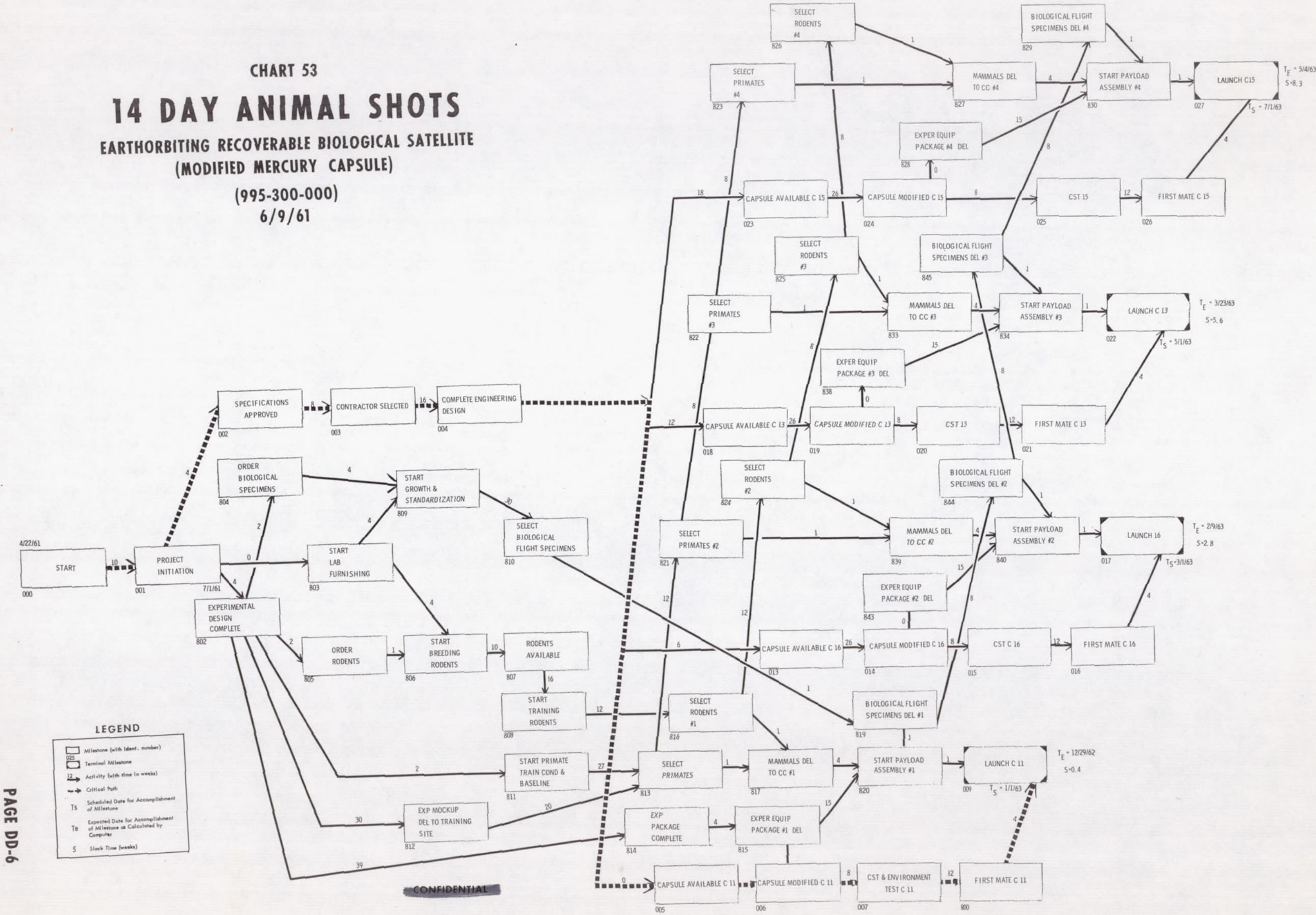
CONFIDEN

CONFIDENTIAL

CHART 53

14 DAY ANIMAL SHOTS

EARTHORBITING RECOVERABLE BIOLOGICAL SATELLITE
(MODIFIED MERCURY CAPSULE)
(995-300-000)
6/9/61



PAGE DD-6

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-300-000	PROJECT GO-AHEAD	0/00/00	0/00/00			0.4
995-300-001	INITIATE SPECIFICATION DEVELOPMENT	7/01/61	7/04/61			0.4
995-300-002	SPECIFICATIONS APPROVED	7/29/61	8/01/61			0.4
995-300-003	CONTRACTOR SELECTED	9/23/61	9/26/61			0.4
995-300-005	CAPSULE AVAILABLE C11	1/13/62	1/16/62			0.4
995-300-004	COMPLETE ENGINEERING DESIGN	1/13/62	1/16/62			0.4
995-300-006	CAPSULE MODIFIED C11	7/14/62	7/17/62			0.4
995-300-007	CST & ENVIRON TEST C11	9/08/62	9/11/62			0.4
995-300-008	FIRST MATE C11	12/01/62	12/04/62			0.4
995-300-009	LAUNCH C11	12/29/62	1/01/63	1/01/63		0.4
995-300-013	CAPSULE AVAILABLE C13	2/24/62	3/15/62			2.8
995-300-014	CAPSULE MODIFIELD C13	8/25/62	9/13/62			2.8
995-300-015	CST C13	10/20/62	11/08/62			2.8
995-300-016	FIRST MATE C13	1/12/63	1/31/63			2.8
995-300-017	LAUNCH C13	2/09/63	2/28/63	3/01/63		2.8
995-300-018	CAPSULE AVAILABLE C15	4/07/62	5/16/62			5.6
995-300-019	CAPSULE MODIFIED C15	10/06/62	11/14/62			5.6
995-300-020	CST C15	12/01/62	1/09/63			5.6
995-300-021	FIRST MATE C15	2/23/63	4/03/63			5.6
995-300-022	LAUNCH C15	3/23/63	5/01/63	5/01/63		5.6
995-300-023	CAPSULE AVAILABLE C16	5/19/62	7/16/62			8.3
995-300-024	CAPSULE MODIFIED C16	11/17/62	1/14/63			8.3
995-300-025	CST C16	1/12/63	3/11/63			8.3
995-300-026	FIRST MATE C16	4/06/63	6/03/63			8.3
995-300-027	LAUNCH C16	5/04/63	7/01/63	7/01/63		8.3

CONFIDENTIAL

Table II

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-300-815	EXPER EQUIP PACKAGE 1 DEL	7/14/62	9/11/62			8.4
995-300-820	START PAYLOAD ASSEMBLY 1	10/27/62	12/25/62			8.4
995-300-843	EXPER EQUIP PACKAGE 2 DEL	8/25/62	11/08/62			10.8
995-300-840	START PAYLOAD ASSEMBLY 2	12/08/62	2/21/63			10.8
995-300-838	EXPER EQUIP PACKAGE 3 DEL	10/06/62	1/09/63			13.6
995-300-834	START PAYLOAD ASSEMBLY 3	1/19/63	4/24/63			13.6
995-300-828	EXPER EQUIP PACKAGE 4 DEL	11/17/62	3/11/63			16.3
995-300-830	START PAYLOAD ASSEMBLY 4	3/02/63	6/24/63			16.3
995-300-812	EXP MOCKUP DEL TO TRAINING SITE	1/27/62	6/07/62	2/01/62		18.8
995-300-813	SELECT PRIMATES 1	6/16/62	10/25/62			18.8
995-300-821	SELECT PRIMATES 2	9/08/62	1/17/63			18.8
995-300-839	MAMMALS DEL TO CC 2	9/15/62	1/24/63			18.8
995-300-814	EXP PACKAGE COMPLETE	3/31/62	8/14/62	4/01/62		19.4
995-300-822	SELECT PRIMATES 3	11/03/62	3/20/63			19.6
995-300-833	MAMMALS DEL TO CC 3	11/10/62	3/27/63			19.6
995-300-823	SELECT PRIMATES 4	12/29/62	5/20/63			20.3
995-300-827	MAMMALS DEL TO CC 4	1/05/63	5/27/63			20.3
995-300-817	MAMMALS DEL TO CC 1	6/23/62	11/27/62			22.4
995-300-802	EXPERIMENTAL DESIGN COMPLETE	7/29/61	1/11/62			23.8
995-300-805	ORDER RODENTS	8/12/61	1/25/62			23.8
995-300-806	START BREEDING RODENTS	8/19/61	2/01/62			23.8
995-300-807	RODENTS AVAILABLE	10/28/61	4/12/62			23.8
995-300-808	START TRAINING RODENTS	2/17/62	8/02/62			23.8
995-300-816	SELECT RODENTS 1	5/12/62	10/25/62			23.8
995-300-824	SELECT RODENTS 2	8/04/62	1/17/63			23.8

CONFIDENTIAL

SMS SYSTEM

DATE 6/13/61 WEEK 127.9 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
995-300-825	SELECT RODENTS 3	9/29/62	3/20/63			24.6
995-300-826	SELECT RODENTS 4	11/24/62	5/20/63			25.3
995-300-803	START LAB FURNISHING	7/01/61	1/04/62			26.8
995-300-804	ORDER BIOLOGICAL SPECIMENS	8/12/61	4/17/62			35.4
995-300-809	START GROWTH AND STANDARDIZATION	9/09/61	5/15/62			35.4
995-300-810	SELECT BIOLOGICAL FLIGHT SPECIMENS	4/07/62	12/11/62			35.4
995-300-819	BIOLOGICAL FLIGHT SPECIMENS DEL 1	4/14/62	12/18/62			35.4
995-300-811	START PRIMATE TRAIN COND AND BASELINE	8/12/61	4/19/62			35.8
995-300-844	BIOLOGICAL FLIGHT SPECIMENS DEL 2	6/09/62	2/14/63			35.8
995-300-845	BIOLOGICAL FLIGHT SPECIMENS DEL 3	8/04/62	4/17/63			36.6
995-300-829	BIOLOGICAL FLIGHT SPECIMENS DEL 4	9/29/62	6/17/63			37.3

CONFIDENTIAL

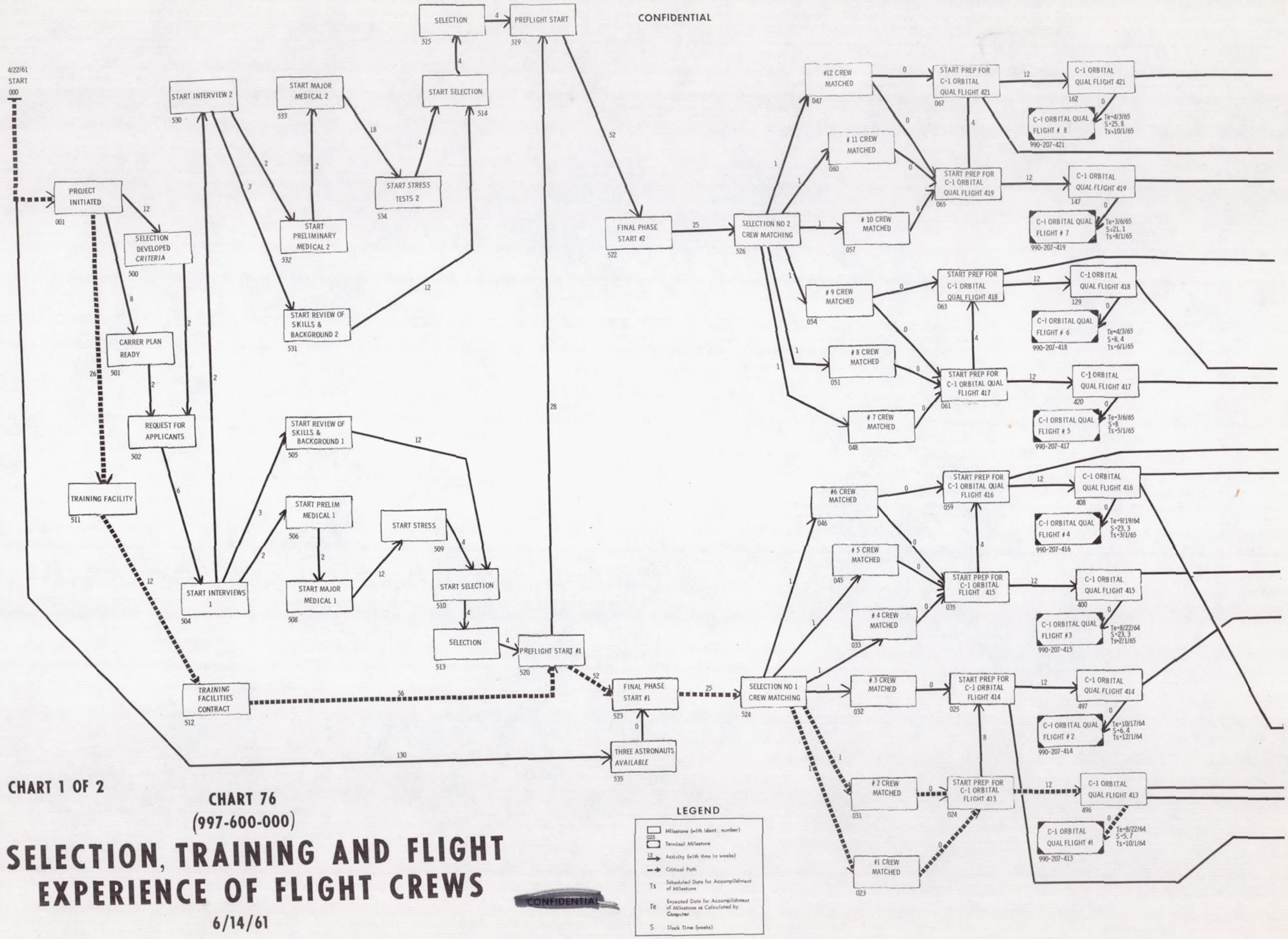


CHART 1 OF 2

PAGE 10a

CHART 76
(997-600-000)

SELECTION, TRAINING AND FLIGHT EXPERIENCE OF FLIGHT CREWS

6/14/61

CONFIDENTIAL

~~CONFIDENTIAL~~

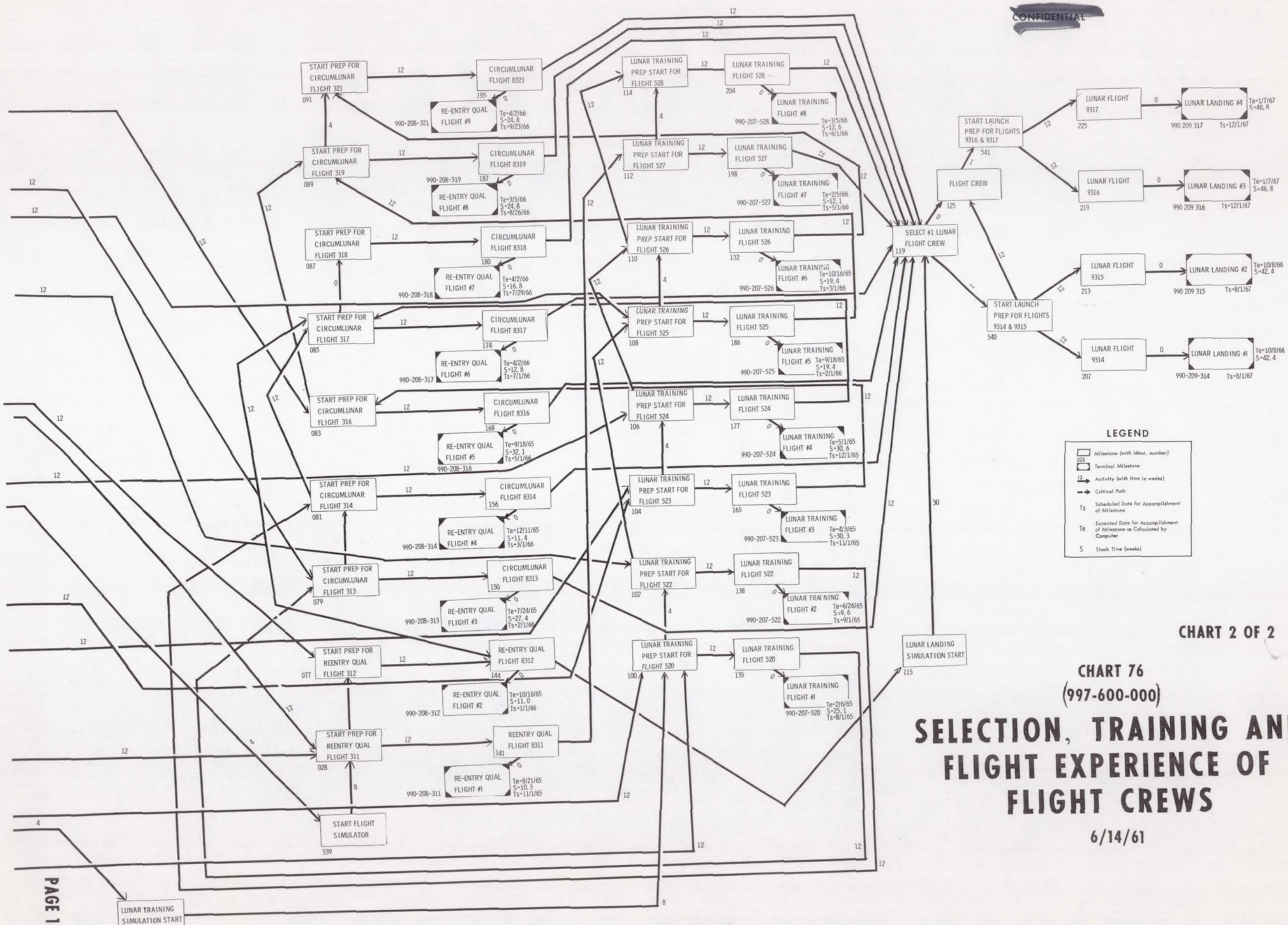


CHART 2 OF 2

CHART 76
(997-600-000)

SELECTION, TRAINING AND FLIGHT EXPERIENCE OF FLIGHT CREWS

6/14/61

~~CONFIDENTIAL~~

CONFIDENTIAL

SMS SYSTEM

DATE 6/14/61 WEEK 128.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
997-600-000	START FLIGHT CREW SEL & TRNG	0/00/00	0/00/00			5.7
997-600-001	PROJECT INITIATED	7/01/61	8/10/61	7/01/61		5.7
997-600-511	TRAINING FACILITY DECISION	12/30/61	2/08/62			5.7
997-600-512	TRAINING FACILITIES CONTRACT	3/24/62	5/03/62			5.7
997-600-520	PREFLIGHT START 1	12/01/62	1/10/63			5.7
997-600-523	FINAL PHASE START 1	11/30/63	1/09/64			5.7
997-600-524	SELECTION NO 1 CREW MATCHING	5/23/64	7/02/64			5.7
997-600-031	2 CREW MATCHED	5/30/64	7/09/64			5.7
997-600-024	START PREP FOR C-1 ORBITAL FLIGHT 413	5/30/64	7/09/64			5.7
997-600-023	1 CREW MATCHED	5/30/64	7/09/64			5.7
990-207-413	C-1 ORBITAL QUAL FLIGHT NO 1	8/22/64	10/01/64	10/01/64		5.7
997-600-496	C-1 ORBITAL QUAL FLIGHT 413	8/22/64	10/01/64	10/01/64		5.7
997-600-025	START PREP FOR C-1 ORBITAL FLIGHT 414	7/25/64	9/08/64			6.4
990-207-414	C-1 ORBITAL QUAL FLIGHT NO 2	10/17/64	12/01/64	12/01/64		6.4
997-600-497	C-1 ORBITAL QUAL FLIGHT 414	10/17/64	12/01/64	12/01/64		6.4
997-600-519	PREFLIGHT START 2	6/15/63	8/10/63			8.0
997-600-522	FINAL PHASE START 2	6/13/64	8/08/64			8.0
997-600-526	SELECTION NO 2 CREW MATCHING	12/05/64	1/30/65			8.0
997-600-048	7 CREW MATCHED	12/12/64	2/06/65			8.0
997-600-061	START PREP FOR C-1 ORBITAL QUAL FLIGHT 417	12/12/64	2/06/65			8.0
997-600-051	8 CREW MATCHED	12/12/64	2/06/65			8.0
997-600-054	9 CREW MATCHED	12/12/64	2/06/65			8.0
990-207-417	C-1 ORBITAL QUAL FLIGHT NO 5	3/06/65	5/01/65	5/01/65		8.0
997-600-420	C-1 ORBITAL QUAL FLIGHT 417	3/06/65	5/01/65	5/01/65		8.0
997-600-063	START PREP FOR C-1 ORBITAL QUAL FLIGHT 418	1/09/65	3/09/65			8.4

CONFIDENTIAL

Table III

CONFIDENTIAL

SMS S Y S T E M

DATE 6/14/61 WEEK 128.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
990-207-418	C-1 ORBITAL QUAL FLIGHT NO 6	4/03/65	6/01/65	6/01/65		8.4
997-600-129	C-1 ORBITAL QUAL FLIGHT 418	4/03/65	6/01/65	6/01/65		8.4
997-600-102	LUNAR TRAINING PREP START FOR FLIGHT 522	4/03/65	6/09/65			9.6
990-207-522	LUNAR TRAINING FLIGHT NO 2	6/26/65	9/01/65	9/01/65		9.6
997-600-138	LUNAR TRAINING FLIGHT 522	6/26/65	9/01/65	9/01/65		9.6
997-600-028	START PREP FOR REENTRY QUAL FLIGHT 311	5/29/65	8/09/65			10.3
990-208-311	NOT TITLED	8/21/65	11/01/65	11/01/65		10.3
997-600-141	REENTRY QUAL FLIGHT 8311	8/21/65	11/01/65	11/01/65		10.3
997-600-077	START PREP FOR REENTRY QUAL FLIGHT 312	7/24/65	10/09/65			11.0
990-208-312	NOT TITLED	10/16/65	1/01/66	1/01/66		11.0
997-600-144	REENTRY QUAL FLIGHT 8312	10/16/65	1/01/66	1/01/66		11.0
997-600-081	START PREP FOR CIRCUMLUNAR FLIGHT 314	9/18/65	12/07/65			11.4
990-208-314	REENTRY QUAL FLIGHT NO 4	12/11/65	3/01/66	3/01/66		11.4
997-600-156	CIRCUMLUNAR FLIGHT 8314	12/11/65	3/01/66	3/01/66		11.4
997-600-535	THREE ASTRONAUTS AVAILABLE	10/19/63	1/09/64			11.7
997-600-112	LUNAR TRAINING PREP START FOR FLIGHT 527	11/13/65	2/05/66			12.1
990-207-527	LUNAR TRAINING FLIGHT NO 7	2/05/66	5/01/66	5/01/66		12.1
997-600-198	LUNAR TRAINING FLIGHT 527	2/05/66	5/01/66	5/01/66		12.1
997-600-114	LUNAR TRAINING PREP START FOR FLIGHT 528	12/11/65	3/09/66			12.6
990-207-528	LUNAR TRAINING FLIGHT NO 8	3/05/66	6/01/66	6/01/66		12.6
997-600-204	LUNAR TRAINING FLIGHT 528	3/05/66	6/01/66	6/01/66		12.6
997-600-085	START PREP FOR CIRCUMLUNAR FLIGHT 317	1/08/66	4/07/66			12.8
990-208-317	REENTRY QUAL FLIGHT NO 6	4/02/66	6/30/66	7/01/66		12.8
997-600-174	CIRCUMLUNAR FLIGHT 8317	4/02/66	6/30/66	7/01/66		12.8
997-600-032	3 CREW MATCHED	5/30/64	9/08/64			14.4

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/14/61 WEEK 128.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
997-600-108	LUNAR TRAINING PREP START FOR FLIGHT 525	6/26/65	11/09/65			19.4
997-600-110	LUNAR TRAINING PREP START FOR FLIGHT 526	7/24/65	12/07/65			19.4
990-207-525	LUNAR TRAINING FLIGHT NO 5	9/18/65	2/01/66	2/01/66		19.4
997-600-186	LUNAR TRAINING FLIGHT 525	9/18/65	2/01/66	2/01/66		19.4
990-207-526	LUNAR TRAINING FLIGHT NO 6	10/16/65	3/01/66	3/01/66		19.4
997-600-132	LUNAR TRAINING FLIGHT 526	10/16/65	3/01/66	3/01/66		19.4
997-600-047	NO 12 CREW MATCHED	12/12/64	5/08/65			21.1
997-600-065	START PREP FOR C-1 ORBITAL QUAL FLIGHT 419	12/12/64	5/08/65			21.1
997-600-060	11 CREW MATCHED	12/12/64	5/08/65			21.1
997-600-057	10 CREW MATCHED	12/12/64	5/08/65			21.1
990-207-419	C-1 ORBITAL QUAL FLIGHT NO 7	3/06/65	8/01/65	8/01/65		21.1
997-600-147	C-1 ORBITAL QUAL FLIGHT 419	3/06/65	8/01/65	8/01/65		21.1
997-600-045	5 CREW MATCHED	5/30/64	11/09/64			23.3
997-600-046	6 CREW MATCHED	5/30/64	11/09/64			23.3
997-600-033	4 CREW MATCHED	5/30/64	11/09/64			23.3
997-600-035	START PREP FOR C-1 ORBITAL FLIGHT 415	5/30/64	11/09/64			23.3
997-600-059	START PREP FOR C-1 ORBITAL QUAL FLIGHT 416	6/27/64	12/07/64			23.3
990-207-415	C-1 ORBITAL QUAL FLIGHT NO 3	8/22/64	2/01/65	2/01/65		23.3
997-600-400	C-1 ORBITAL QUAL FLIGHT 415	8/22/64	2/01/65	2/01/65		23.3
990-207-416	C-1 ORBITAL QUAL FLIGHT NO 4	9/19/64	3/01/65	3/01/65		23.3
997-600-408	C-1 ORBITAL QUAL FLIGHT 416	9/19/64	3/01/65	3/01/65		23.3
997-600-089	START PREP FOR CIRCUMLUNAR FLIGHT 319	12/11/65	6/02/66			24.8
997-600-091	START PREP FOR CIRCUMLUNAR FLIGHT 321	1/08/66	6/30/66			24.8
990-208-319	NOT TITLED	3/05/66	8/25/66	8/26/66		24.8
997-600-187	CIRCUMLUNAR FLIGHT 8319	3/05/66	8/25/66	8/26/66		24.8

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/14/61 WEEK 128.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
990-208-321	NOT TITLED	4/02/66	9/22/66	9/23/66		24.8
997-600-195	CIRCUMLUNAR FLIGHT 8321	4/02/66	9/22/66	9/23/66		24.8
997-600-029	LUNAR TRAINING SIMULATION START	9/19/64	3/13/65			25.1
997-600-100	LUNAR TRAINING PREP START FOR FLIGHT 520	11/14/64	5/08/65			25.1
990-207-520	LUNAR TRAINING FLIGHT NO 1	2/06/65	8/01/65	8/01/65		25.1
997-600-135	LUNAR TRAINING FLIGHT 520	2/06/65	8/01/65	8/01/65		25.1
997-600-067	START PREP FOR C-1 ORBITAL QUAL FLIGHT 421	1/09/65	7/08/65			25.8
990-207-421	C-1 ORBITAL QUAL FLIGHT NO 8	4/03/65	9/30/65	10/01/65		25.8
997-600-162	C-1 ORBITAL QUAL FLIGHT 421	4/03/65	9/30/65	10/01/65		25.8
997-600-079	START PREP FOR CIRCUMLUNAR FLIGHT 313	5/01/65	11/09/65			27.4
990-208-313	NOT TITLED	7/24/65	2/01/66	2/01/66		27.4
997-600-150	CIRCUMLUNAR FLIGHT 8313	7/24/65	2/01/66	2/01/66		27.4
997-600-500	SELECTION CRITERIA DEVELOPED	9/23/61	4/07/62			28.0
997-600-502	REQUEST FOR APPLICANTS	10/07/61	4/21/62			28.0
997-600-504	START INTERVIEWS 1	11/18/61	6/02/62			28.0
997-600-530	START INTERVIEW 2	6/02/62	12/15/62			28.0
997-600-532	START PRELIMINARY MEDICAL 2	6/16/62	12/29/62			28.0
997-600-533	START MAJOR MEDICAL 2	6/30/62	1/12/63			28.0
997-600-534	START STRESS TESTS 2	11/03/62	5/18/63			28.0
997-600-514	START SELECTION 2	12/01/62	6/15/63			28.0
997-600-515	SELECTION 2	12/29/62	7/13/63			28.0
997-600-104	LUNAR TRAINING PREP START FOR FLIGHT 523	1/09/65	8/09/65			30.3
990-207-523	LUNAR TRAINING FLIGHT NO 3	4/03/65	11/01/65	11/01/65		30.3
997-600-165	LUNAR TRAINING FLIGHT 523	4/03/65	11/01/65	11/01/65		30.3
997-600-106	LUNAR TRAINING PREP START FOR FLIGHT 524	2/06/65	9/08/65			30.6

CONFIDENTIAL

CONFIDENTIAL

SMS SYSTEM

DATE 6/14/61 WEEK 128.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
990-207-524	LUNAR TRAINING FLIGHT NO 4	5/01/65	12/01/65	12/01/65		30.6
997-600-177	LUNAR TRAINING FLIGHT 524	5/01/65	12/01/65	12/01/65		30.6
997-600-506	START PRELIM MEDICAL 1	12/02/61	7/12/62			31.7
997-600-508	START MAJOR MEDICAL 1	12/16/61	7/26/62			31.7
997-600-509	START STRESS TESTS 1	3/10/62	10/18/62			31.7
997-600-510	START SELECTION 1	4/07/62	11/15/62			31.7
997-600-513	SELECTION 1	5/05/62	12/13/62			31.7
997-600-501	CAREER PLAN READY	8/26/61	4/07/62			32.0
997-600-083	START PREP FOR CIRCUMLUNAR FLIGHT 316	6/26/65	2/05/66			32.1
990-208-316	REENTRY QUAL FLIGHT NO 5	9/18/65	5/01/66	5/01/66		32.1
997-600-168	CIRCUMLUNAR FLIGHT 8316	9/18/65	5/01/66	5/01/66		32.1
997-600-539	START FLIGHT SIMULATOR	10/17/64	6/14/65			34.3
997-600-505	START REVIEW OF SKILLS & BACKGROUND 1	12/09/61	8/23/62			36.7
997-600-531	START REVIEW OF SKILLS & BACKGROUND 2	6/23/62	3/23/63			39.0
997-600-115	LUNAR LANDING SIMULATION START	12/11/65	10/04/66			42.4
997-600-119	SELECT 1 LUNAR FLIGHT CREW	7/09/66	5/02/67			42.4
997-600-540	START LAUNCH PREP FOR FLIGHTS 9314 & 9315	7/16/66	5/09/67			42.4
990-209-315	LUNAR LANDING NO 2	10/08/66	8/01/67	8/01/67		42.4
990-209-314	LUNAR LANDING NO 1	10/08/66	8/01/67	8/01/67		42.4
997-600-207	LUNAR FLIGHT 9314	10/08/66	8/01/67	8/01/67		42.4
997-600-213	LUNAR FLIGHT 9315	10/08/66	8/01/67	8/01/67		42.4
997-600-125	SELECT 2 LUNAR FLIGHT CREW	10/08/66	8/31/67			46.8
997-600-541	START LAUNCH PREP FOR FLIGHTS 9316 & 9317	10/15/66	9/07/67			46.8
990-209-317	LUNAR LANDING NO 4	1/07/67	11/30/67	12/01/67		46.8
990-209-316	LUNAR LANDING NO 3	1/07/67	11/30/67	12/01/67		46.8

CONFIDENTIAL

Table III

CONFIDENTIAL

SMS SYSTEM

DATE 6/14/61 WEEK 128.0 SEQUENCE 10

EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK
997-600-219	LUNAR FLIGHT 9316	1/07/67	11/30/67	12/01/67		46.8
997-600-225	LUNAR FLIGHT 9317	1/07/67	11/30/67	12/01/67		46.8
990-208-318	NOT TITLED	4/02/66	7/28/66	7/29/66		16.4
997-600-180	CIRCUMLUNAR FLIGHT 8318	4/02/66	7/28/66	7/29/66		16.4
997-600-087	START PREP FOR CIRCUMLUNAR FLIGHT 318	1/08/66	5/01/66			16.4

CONFIDENTIAL

Table III

CONFIDENTIAL

PART II

Section E

SPACE SCIENCE CONTRIBUTIONS

TO THE

MANNED LUNAR LANDING EFFORT

W. S. Shipley
Office of Lunar
and Planetary Programs

Robert Fellows
Office of Scientific Satellites
and Sounding Rocket Programs

June 16, 1961

CONFIDENTIAL

CONTENTS

SPACE SCIENCE CONTRIBUTIONS

Scientific Satellite and Sounding Rocket and Lunar and Planetary Programs

SUMMARY

The missions of the Scientific Satellite and Sounding Rocket Programs and the Lunar and Planetary Programs support the manned landing effort by evaluating the cislunar and lunar environment, and by developing the technology of space navigation.

The scientific satellites and sounding rockets are being instrumented to investigate the spectra of energetic particles, the intensity and direction of magnetic fields (which control particle motion) and the frequency of occurrence and size of micrometeorites, in the vicinity of the earth. The origin and mechanics of transport of the energetic particles are to be further studied by space probes and interplanetary spacecraft. The various subcommittees of the NASA Space Sciences Steering Committee have regularly reviewed the instrument complements of each of the established missions to assure optimization of their contributions to understanding the field and particle environment. The results of the current measurements, and those made over the last solar cycle, are being collated in a theoretical study funded by NASA, to assess the current state of knowledge. It should be noted that a program to develop capability to predict intense solar flares by ground-based observations of the sun is also in progress under NASA sponsorship.

In order to assure proper assessment of the space environment commensurate with the design schedule of the manned lunar spacecraft, it is recommended that the launching rate of earth satellites and sounding rockets be increased by a factor of two commencing in FY 1963. It is further recommended that the Ranger A spacecraft program be extended to include two additional launchings, to increase the spatial and temporal coverage of the interplanetary environment.

The three Ranger B lunar spacecraft, to be fired in the second half of FY 1962, are to provide limited lunar topographic and radiation data from bus-mounted instruments,

before deployment of the so-called hard landing capsules. The capsules are to carry seismometers for determination of the lunar surface motions and body properties. In order to support the manned landing it is intended to add four Ranger B firings in FY 1963. These flights are to increase the topographic data on the lunar surface by means of high resolution, high frame rate, TV carried on impacting busses, and to determine the surface hardness by means of penetrometer capsules. The cislunar radiation environment is to be measured on each additional Ranger B flight. The importance of these early Ranger A and B firings cannot be overemphasized, since their results will shape the following missions.

The Surveyor A soft landing lunar spacecraft is instrumented to obtain data on the lunar surface texture, profile, structure, physical properties, chemistry, mineralogy, and radiation environment. In order to assure receipt of these data prior to the design freeze of manned lunar spacecraft, the number of firings in the first half of FY 1964 has been increased from one to three, and the total number of Surveyors (A and B) has been increased from 11 to 23. The Surveyor B lunar orbiter will provide topographic data for various locations on the moon, as a basis for extrapolation of data from the point landing sites of the Surveyor A to other locations. The orbiter will also measure the particle and field environment in the vicinity of the moon. It is recommended that the Surveyor B be programmed to provide two flights by the end of the first half of FY 1965.

The Prospector, the third-generation lunar spacecraft, is to be designed as a carrier for selected lunar experiments and equipment in preparation for, and in operational support of, the manned lunar landing. Due to the large landing weight of the Prospector, about four tons, integration of experiments need not dominate the spacecraft design. The variety of missions considered for Prospector now include: low altitude lunar reconnaissance, utilizing the vernier engines for hovering, a roving vehicle for transporting experiments, equipment, or man on the lunar surface, sample or experiment return to earth, radio aids and TV cameras to assist and monitor the manned landing, and transport of life and material support for manned lunar exploration.

In addition to the scientific and operational support, the unmanned missions provide evolutionary steps, through multiple shot series, in the development of space flight

technology. It is readily apparent that many of the techniques, systems, and components developed for, and flight-proven in, the unmanned spacecraft programs will contribute directly to manned lunar exploration.

The space science flight program recommended to support the manned lunar landing effort is summarized in Figures E-1 and E-2.

Figure E-1

Satellite and Sounding Rocket Programs

	Calendar Year						
	1961	1962	1963	1964	1965	1966	1967
Earth Satellites							
S-3 type	▼O	▼O	O				
EGO			▼OO	O	O	O	O
OSO	▼	▼ O	O ▼	O	O	O	O
Sounding Rockets							
Solar flare standby	← 12 per year O →						
Journeyman (ARGO D-8)	← 4 per year O →						
Recoverable Experiments							
Modified Mercury capsules		O OO					
Satellites (4,000 - 5,000 n. mi.)			O OO	OO	O	O	O

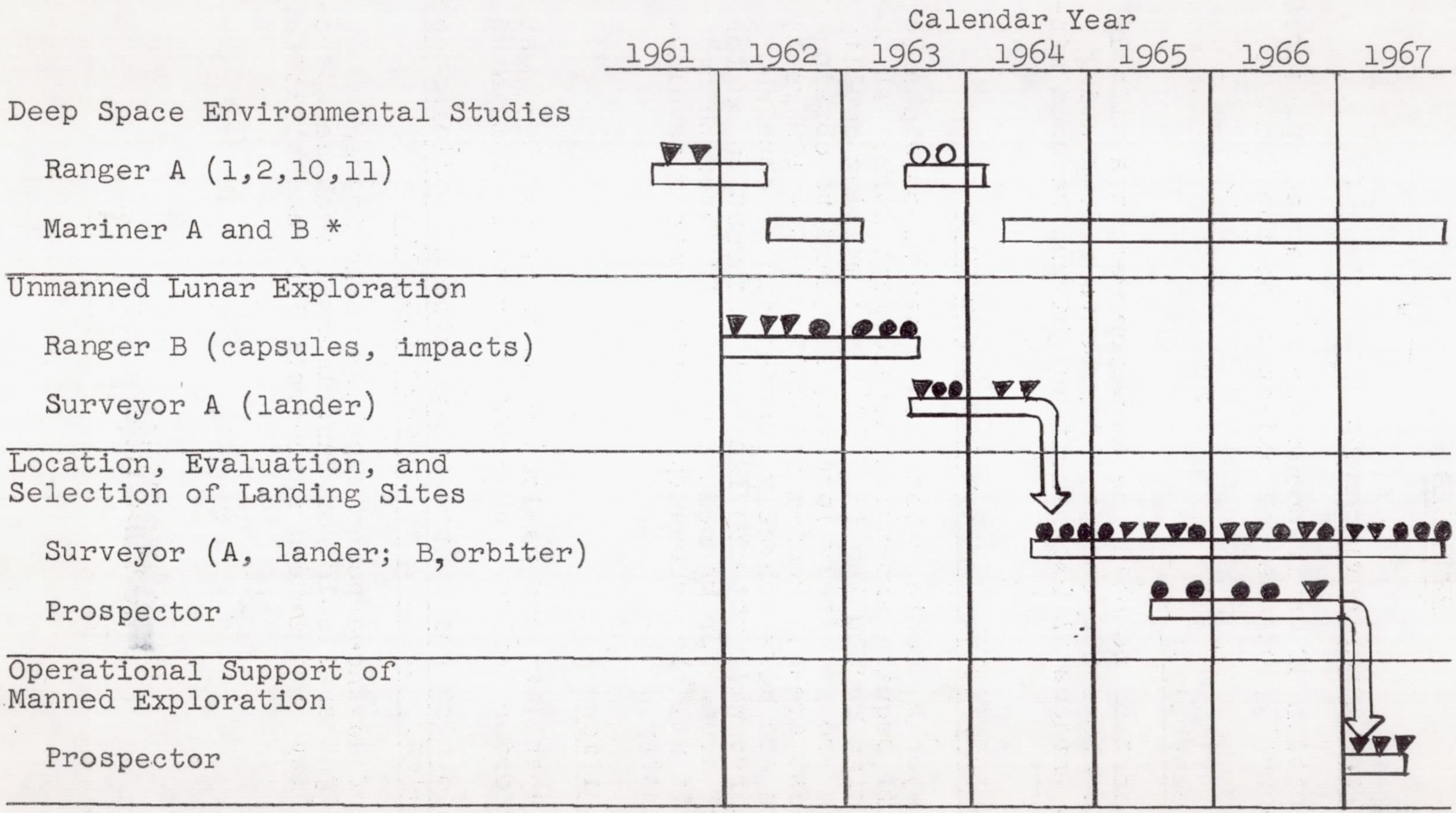
Legend:

▼ Present schedule

O Recommended additions

Figure E-2

Unmanned Lunar Flight Program



* Part of planetary program; funded separately

Legend:

▼ Missions included in establishing the original FY 1962 budget estimates
● Missions included in the revised FY 1962 budget estimates
○ Missions recommended as a result of this study

PROBLEMS

1. Cislunar and lunar environment

The definition of environment for the manned spacecraft program has actually become the objective of the unmanned missions.

2. Centaur capability

It is important to hold the Surveyor weight available to experiments above 200 pounds. Any Centaur downrating makes serious inroads in experiment weight and reduces mission value.

3. Photo reconnaissance system for Surveyor B

The Surveyor B, Centaur-launched lunar reconnaissance satellite, will require extensive development work. At the present time high resolution (5 - 10 feet) mapping quality pictures which are precisely located, are hard to obtain over even modest areas. Medium resolution (50 - 100 feet) pictures which are more coarsely located can be obtained but such pictures will not provide much information on the suitability of areas for manned landing. If "everything" is required, it will be necessary to enter into a development with industry.

4. C-3 definition

Weight capability and payload envelop of the C-3 must be defined in order for work on Prospector to be initiated.

5. The development and system integration of radioisotope, thermonuclear, or fuel cell power supplies

The use of advanced power supplies could increase spacecraft weight available for experiments, enhance spacecraft reliability, and extend spacecraft life capabilities.

MAJOR DECISIONS AND ADMINISTRATIVE PROBLEMS

1. S-3 project

Thor Delta launch vehicles must be provided for the additional S-3 satellites in FY 1962.

2. Early lunar orbiters

OSFP must examine the problems involved in the recommendation for early lunar orbiters. (See Appendix II)

3. Ranger

How is the Ranger follow-on project to be executed?

a. Additional spacecraft busses
b. Additional experiments

Action is required immediately.

4. Ranger

Additional Agenas must be obtained for the Ranger follow-on program.

5. Prospector

The major decision with regard to Prospector and how it is to be handled must be made by the end of CY 1961.

6. Voyager

A major decision with regard to what Voyager should be, and what launch vehicle is to be used, must be made by the end of CY 1961.

7. Facilities

Larger amounts, proportionately several times larger than at present, must be allocated for facilities. Available environmental test facilities are not commensurate with the reliability needed in the spacecraft missions, and previously planned field checkout facilities are not adequate to support the recommended firing rate.

8. DSIF

Provisions must be made to increase the DSIF capability to support the recommended increased firing rate.

SPACE SCIENCE CONTRIBUTIONS

INTRODUCTION

The missions of the Scientific Satellite and Sounding Rocket Programs and the Lunar and Planetary Programs were conceived with the sole intent of expanding man's knowledge of the basic processes and history of the solar system. Repeated examinations of these missions have established that their gross objectives are identical with those of a program oriented toward preparation for a manned lunar landing; with the exception that more emphasis might be placed on bioscientific missions, such as transporting living creatures to and from the moon, to determine the biological effects of the measured environment. Recognizing this congruence of objectives as a manifestation of the dependence of design engineering on basic science, the intent of this study has been to relate the acquisition of information from the unmanned missions to the design schedule for the manned spacecraft program. Consideration of the 1967 date has resulted in recommendations for additional firings and reorientation of experiments in the existing projects. No additional projects have been recommended, however, additional projects may be required as the detailed design of certain critical projects proceeds, or as the results of the early experiments are brought to bear on the program.

The contributions of the unmanned missions to the manned landing program can be grouped in five categories:

- Geophysical and Solar Studies
- Deep Space Environmental Studies
- Unmanned Exploration of the Moon
- Location, Evaluation and Selection of Lunar Landing Sites
- Operational Support of Manned Lunar Exploration

The geophysical and solar studies use earth satellites, high altitude probes, and sounding rockets, to study and continuously monitor the upper atmosphere and near earth region of space, and to study the solar phenomena and the effects of solar activity on the geophysical processes. Deep space probes are used to continuously study interplanetary phenomena and the role of the sun in determining the interplanetary environment. The unmanned lunar missions provide

a sequence of evolutionary steps in the development of the technology of space navigation and lunar landing, simultaneously defining the lunar surface and the cislunar environment.

It might well be said that the recommended space science program supports the manned landing program in a relatively conservative manner. The literature contains many theoretical studies which assert to predict the cislunar and lunar environment and the lunar surface characteristics. Since there is considerable disagreement among the resulting predictions, no attempt has been made to summarize the literature in this report, except for limited reference to the certain interpretations of previous space experiments. The recommended program is designed to provide measurements of the quantities in question so that suitable theories may be selected or verified and design criteria developed.

GEOPHYSICAL AND SOLAR STUDIES

The NASA programs in this category are carried out with the objective of increasing our knowledge and understanding of (1) the region of space in the vicinity of the earth, (2) the sun and its physical processes, and (3) the role of the sun in determining geophysical events. In varying degrees, work toward these objectives contributes to the solution of the problems of manned space flight. It is generally accepted that one of the important problems in manned space flight is the radiation hazard presented by the space environment.

The radiation hazard may be considered in terms of three different types of natural phenomena. The first of these, bursts of protons released by the sun during some solar flares, probably constitute the most unpredictable intense radiation hazard. The second radiation hazard is the trapped energetic particles in the regions around the earth generally referred to as the Van Allen radiation belts. The third type of radiation hazard is that presented by galactic cosmic rays.

These three types of radiation, and the nature of the hazard presented by each are discussed in Appendix I.

The basic objectives of the scientific program are not altered in the least by an increased emphasis on manned space flight. However, the consideration of manned flight in the late 1960's does place a requirement on the rate of acquisition of information that did not exist when the space science program was planned. It is obvious that most of this sense of urgency is centered about our uncertainties about the behavior of the sources of radiation and the undertainties about the effects of the radiation on man. Therefore, the recommendations for geophysical and solar studies support to a manned lunar program consist of increases in level of effort.

Radiation belt satellites

A Thor-Delta-launched satellite designed specifically for radiation belt studies is scheduled for launching in August, 1961. Another one is scheduled for launching in May, 1962. It is recommended that three additional satellites of this type be provided to furnish flight back-up for the two scheduled for December, 1961, or as much earlier as one could be launched if the August launch fails, and September, 1962.

These two, therefore, furnish flight back-up and also would be available in event that the satellites have a useful life of only several months. The third addition should be scheduled for launching about March, 1963, if the new and larger S-49 EGO satellite slips its present schedule. Obviously, the intention here is to try to start securing information about the radiation belts and to start continuously monitoring the radiation in space at as early a time as possible. A description of the satellite, its particle detectors, and the magnetometers to be carried is available in other NASA documents and will not be given here.

Eccentric geophysical observatories (EGO)

The first of this series of satellites is scheduled for March, 1963, at which time the S-3 type will be phased out. It will be capable of carrying many more instruments than S-3 and, therefore, will be able to provide much more valuable data in terms of both a wider scope of measurements and the simultaneous observation of other geophysical and solar phenomena. It is recommended that two additional satellites and vehicles be provided for the S-49 launch at about three-month intervals to insure the successful orbiting of radiation belt satellites when S-3 is phased out. Thereafter, EGO's on six-month centers are recommended to provide back-up and more certainty of continuous monitoring than is provided by the 10 year plan of one per year. The instrumentation for the first EGO is being firmed-up at this time and will contain over 100 lbs. of energetic particles detectors and magnetometers. In addition, radio astronomy experiments (including solar studies) and ionospheric measurements will be performed.

Solar observatory satellites

Three of these are on the present flight schedule. The first of these will be launched about September, 1961 and the second is scheduled for about six months later. The third is scheduled for September, 1963, about one and one-half years after the second. It is recommended that two additional satellites and vehicles be provided at six-month intervals within this one and one-half year gap to provide adequate back-up and continuous monitoring assurance. Continuous monitoring of solar phenomena and electromagnetic radiations, particularly in the x-ray, gamma-ray, and ultraviolet, are considered to be vital in enlarging our understanding of solar

phenomena. So little is known about solar flare prediction that continuous monitoring is deemed essential to the development of flare prediction techniques. Solar observatory satellites are essential because the measurements can not be made from the ground due to absorptions by the earth's atmosphere and the duration of useful measurements by balloons and sounding rockets is quite short.

Journeyman (ARGO D-8) launches

In the Fall of 1960, a rocket of this type successfully carried a payload of recoverable emulsions (NERV) 1,200 miles high into the inner radiation belt off the shore of Southern California. Four launches of this type carrying life sciences experiments are presently scheduled. It is recommended that four launches of this type per year be carried out to continue the detailed study of the inner radiation belt. Attention should be called to the fact that due to orbital peculiarities the orbits of the S-3 and EGO satellites will not cover the heart of the inner belt. In addition, photographic emulsions offer the possibility of conducting more detailed and definitive study than can be done with satellite instrumentation. Emulsions, of course, suffer from the disadvantage that recovery is necessary.

Solar flares program

During the Summer and Fall of 1960 Nike-Cajun sounding rockets carrying recoverable emulsion payloads were held available on a standby basis at Fort Churchill for launching in event of a solar flare. In mid-November a large flare occurred and very valuable data were obtained from the series of launches. In addition, important simultaneous supporting measurements were also obtained from balloon launchings and by Explorer VII which was still successfully reporting some radiation data. It is recommended that this standby program be continued even though the probability of flares will decrease for the next few years. This recommendation is made on the basis that so little is known concerning solar flares and their prediction that we can't afford to miss any opportunity of studying them. This effort in terms of cost and manpower is very modest. The measurements must be made at latitudes where the earth's magnetic field permits the proton bursts to be detected at sounding rocket altitudes. Fort Churchill is quite suitable.

Solar flare prediction

GSFC has underway a program designed with this objective in mind. Involved in this program are GSFC scientists, consultants, and supporting theoretical studies. This program was initiated without the strong sense of time urgency that now exists because of the consideration being given to acceleration of manned space flight. It is strongly recommended that the level of effort in this program be considerably increased and the studies enlarged to include the following activities.

a. Studies of the solar-interplanetary magnetic field

b. Studies of complete spectrum of solar radio emissions

c. Monitoring of solar bright plages in the light of hydrogen and calcium lines

d. Studies of hot spots in the solar corona

e. Monitor and determine the history of active centers

f. Thorough review, analysis, and coordination of all sun-spot and solar data accumulated to date

g. Increased emphasis on theoretical studies of solar processes

h. Studies of the magnetic fields associated with solar proton bursts

The activities listed above can be pursued through a coordinated program involving satellite sounding rocket and balloon instrumentation, ground monitoring stations (in existence, but their observations should be closely coordinated into the program on a timely basis), an increased effort at analyzing and coordinating results of the IGY and earlier data, and a much stronger program in theoretical solar physics in the university program.

Our present knowledge of the physics of solar flares is very limited. We do not understand the mechanism which triggers them. Therefore, a program of the type outlined above may be the key factor in establishing solar flare prediction criteria.

Recoverable Mercury capsules

Life Sciences has recommended three launches of modified Mercury capsules for CY 1962. These will carry living specimens. Recoverable emulsions and physical instrumentation should be aboard to supply the physical data needed to describe the radiation exposure.

Recoverable high altitude satellite

Both the life scientists and the geophysicists have strongly recommended the development of a stabilized recoverable satellite to be launched into a 4,000 to 5,000 mile orbit for studies of the effects and the composition of the inner belt. Recovery is essential for studies with living specimens, and if recovery is available, photographic emulsions are well suited for the physical measurements of the radiation. The Office of Life Sciences Programs has requested four satellites of this type for studies during FY 1962. Thereafter, it is recommended that at least one successful launch per year be achieved to provide for a continuing study of this region over this course of the solar minimum and rise in activity between now and 1967. This portion of the radiation belt region is not studied in detail by the S-3 and EGO satellites due to the inclination and eccentricity of their orbits.

Summary note

In conclusion, attention should be drawn to the fact that the radiation problem is highly involved and complicated. The radiation belts and the intense bursts of solar protons have been studied for only a few years. We do know that the outer radiation belt and the solar protons are strongly dependent upon solar activity and the magnetic field behavior between the earth and the sun. It appears quite obvious that a strongly coordinated scientific program involving geophysical studies, solar studies, and interplanetary space studies over the course of a solar cycle will be necessary to gain an insight into the phenomena that have formed the discussion topic of this section.

Likewise, it is true that there are other areas of concern to manned space flight in which the space sciences programs can be of supporting assistance. Two of these areas are (1) atmospheric structure and composition data as applying to reentry problems, and (2) micrometeorite flux rate and penetration considerations. In these areas it is felt that on the basis of foreseeable problems, the present NASA flight program in satellites, sounding rockets, and space probes will support a manned lunar program without the need for an increased level of effort at this time.

DEEP SPACE ENVIRONMENTAL STUDIES

Definition of the cislunar environment requires an understanding of the dynamic phenomena of the solar system and is thus dependent on measurements made from Ranger and Mariner interplanetary spacecraft.

Ranger project

Although the ultimate goal of the Ranger project is the landing of instrumentation on the moon, the initial two firings of the series are to be developmental flights having earth satellite orbits rather than lunar impact trajectories. The orbits of Ranger 1 and 2 are highly eliptical, nominal apogee of 685,000 miles and period of 53 days, providing an opportunity for extensive measurement of the interplanetary radiation, magnetic field, and micrometeorite environment. The approximate spectrum of charged particles of energies ranging from ten to a billion electron volts will be measured. Electrostatic analyzers will measure the low energy particle flux or plasma as a function of charge sign, energy per unit charge, and direction of travel. The data obtained from the electrostatic analyzers should make it possible to choose among three theoretical models of the mechanism of transport of the solar plasma. The characteristics of the radiation in the energy range from a few kev to a few mev will be measured by a group of charged particle detectors including semiconductor devices and geiger counters. The intensity and direction of travel of high energy particles in energy ranges above 1 mev and above 10 mev, will be measured by unshielded and shielded triple coincidence counter telescopes, and the ionization of the high energy radiation is to be measured by a Nehr ionization chamber. For precise measurement of the magnetic field that guides the high energy particles the Ranger will carry a rubidium vapor magnetometer.

The data from the Ranger fields and particles experiments will be correlated with that from satellites, sounding rockets and earth-based observatories, in order to increase the understanding of the origin of the particles and their mechanism of transport. An understanding of these phenomena is a prerequisite to the accurate prediction of the radiation environment to be encountered in space travel.

The Ranger 1 and 2 spacecraft will also carry a cosmic dust experiment to provide data on the micrometeorite hazard. These cosmic dust experiments are designed to measure the flux

of dust particles as functions of particle energy, momentum, and direction of travel. The energies of the particles will be indicated by the magnitude of the response of a scintillator-photomultiplier detector, and the momentum will be indicated by the response of a crystal microphone attached to the scintillator. Comparison of the forward and retrograde flux will be obtained since the detector will point toward the west of the ecliptic plane during the first half of the orbit and toward the east during the second half.

Mariner project

Due to the temporal variations in the solar processes it is desirable to have field and particle experiments continuously active on deep space probes as well as earth satellites. After the Ranger 1 and 2 firings in 1961, planetary spacecraft will be flown in 1962 and 1964, and at an average rate of two per year thereafter. Although the primary experiments of the Mariner A and B spacecraft are to be oriented toward the study of Venus and Mars, respectively, field and particle and cosmic dust experiments are to monitor the interplanetary environment. These interplanetary experiments, though considerably more sophisticated, are to measure the same physical phenomena as their Ranger counterparts.

In light of the critical need for definition of the space environment resulting from the influence of the environment on the weight of the manned craft it is recommended that the Ranger program be extended to include two additional interplanetary firings during 1963. At present there are no interplanetary probes scheduled in 1963. These firings have not been approved and are not funded in the FY 1962 budget. Funding should be obtained in the FY 1963 and FY 1964 budgets to permit firings in early FY 1964. This timing would allow modification of the experiments to exploit data obtained from the Ranger 1 and 2 firings.

UNMANNED EXPLORATION OF THE MOON

The unmanned exploration of the moon is to be carried out by the Ranger and Surveyor A spacecraft projects, utilizing the Atlas Agena and Atlas Centaur boost vehicles, respectively. The Ranger project is directed toward the rough landing of instrumented capsules on the lunar surface and, through its series of missions, is to provide measurements of the space environment and limited data on the lunar surface topography, structure and environment. The Surveyor A, a more complex spacecraft than the Ranger, is to soft-land about 250 lbs. of instrumentation on the surface of the moon. The first three Surveyor A spacecraft should provide sufficient data on the lunar surface for the initial design of the manned landing spacecraft.

Ranger B project

The Ranger 3, 4 and 5 spacecraft are to rough-land a capsule, containing a single-axis seismometer, in the vicinity of Letronne at the edge of Oceanus Procellarum. This experiment is to monitor lunar seismic activity for a period of from one to three months. The resulting data are to be used for the determination of distances to sources of seismicity, estimates of the seismic energy released, indications of seismic absorptivity of the lunar material, and possible establishment of the existence of a liquid lunar core.

In addition to the capsule and its rough-landing system the Ranger 3, 4 and 5 spacecraft will carry vidicon and gamma-ray spectrometer experiments. The vidicon experiment is of considerable interest to the manned landing program since it is to provide pictures of the surface with a resolution nearly two orders of magnitude better than can be obtained from earth. The vidicon experiment is to take about 100 pictures during the descent of the spacecraft bus. The first picture, taken from an altitude of about 2,000 miles, will have a field of view 25 miles square with a resolution between 600 and 1,200 feet; the last picture taken from less than 100,000 feet will have a field of view about 2,000 feet square and a resolution of 10 to 20 feet. The gamma-ray spectrometer will provide data on the natural radioactivity of the lunar surface and the relative abundance of radioactive elements in the lunar surface.

Extension of the Ranger program to include four additional firings has been approved. It is recommended that the

seismometer experiment be replaced (in the additions) with two alternate, interchangeable experiments, a rough-landed penetrometer capsule, and a high-frame-rate, high-resolution television package to impact the moon with the spacecraft bus. The penetrometer capsule should be instrumented to telemeter the acceleration history of the impact to provide data on the hardness of the lunar surface. The television experiment should have a sufficiently high frame rate to provide pictures from a low enough altitude to achieve resolution of about 1/2 foot. Since the restrictions on the Ranger landing site result from the vertical approach required for the retro system, the TV experiment could be performed at several points in Oceanus Procellarum, one of the areas currently considered for the manned landing. Indeed, the value of the TV experiment would be enhanced if stereo pictures were taken from an angle with respect to the vertical, provided the angle were known and sufficiently small as not to require image motion compensation.

It is further recommended that the gamma-ray spectrometer be replaced by a field and particles experiment to establish the nature of the radiation environment in the vicinity of the moon. The possibility of a lunar satellite for fields and particles experiments in FY 1963 should be considered by the Office of Space Flight Programs. No lunar satellite has been included in the recommended program prior to CY 1964, for two reasons. First, the orbiter is felt to have lower priority than the other recommended missions; and secondly, there are at least two means of performing such a mission, their relative merits depending on other NASA programs. The most desirable way of placing a fields and particles experiment in a lunar orbit might be to use the Ranger spacecraft as a launching platform. Other approaches might use the Atlas Able 5 system, or a new development based on the Agena B. Some conclusion on the necessity of an orbiter, and the most desirable approach, should be reached by the Office of Lunar and Planetary Programs in the next few months.

Surveyor A project

The Surveyor A is to be the first true lunar soft-landing spacecraft. This spacecraft system is to have the capability of landing within about 20 miles of any chosen location on the moon, and the communications system provides location of the spacecraft within a mile after landing. It is planned to land Surveyor spacecraft in the maria regions which are the proposed sites for the manned landing.

The Surveyor spacecraft will carry an extensive complex of experiments to investigate the lunar topography, structure and environment.

Three television cameras are to perform a complete survey of the lunar terrain, from the immediate vicinity of the spacecraft to the horizon, through all azimuth angles. In order to increase the probability of success of the experiment the cameras have been arranged with sufficient overlap of scanning view to obtain nearly complete coverage by two of the cameras if one should fail. In addition to redundancy, this arrangement provides limited stereo capability. The three cameras are to be equipped with three color filters so that color pictures can be constructed from the telemetered data. A fourth camera is oriented toward the base of the spacecraft for observation of the landing site during approach and for monitoring the lunar drill performance.

The lunar drill is one of the key Surveyor experiments. Observation of the drill penetration rate provides a direct measure of the surface and subsurface hardness. Material from the drill is to be pulverized and passed to a gas chromatograph, an x-ray fluorescence spectrograph, and an x-ray diffractometer. The gas chromatograph is to detect and identify a limited number of organic molecules which might constitute primordial life forms. The x-ray fluorescence spectrograph is capable of detecting the presence of about 13 selected elements, if present in amounts between 0.1 and 1 per cent. The x-ray diffractometer is to identify minerals in the lunar surface from sample diffraction patterns. The diffractometer results, combined with the elemental analysis performed by the x-ray spectrograph, will provide significant data on the lunar surface composition. In addition to providing samples of the surface material for analysis and data on the hardness of the lunar surface and subsurface, the drill is to prepare a hole for insertion of a physical parameters probe which will permit measurement of the surface material density, electrical properties and speed of sound. A similar physical parameters experiment is to be slowly driven into the lunar surface and another located on the surface.

The lunar body properties are to be studied by a seismometer experiment. The instrument under consideration is a three-axis unit with a sensitivity of a few millimicrons.

The lunar surface atmosphere is to be measured by a modified Redhead pressure gage with an operating range of about 10^{-18} to 10^{-13} atmospheres.

The Surveyor is to land two radiation experiments and a magnetometer on the moon. A plasma probe is to measure the incidence of low energy particles on the lunar surface, and indicate the variation in the plasma intensity from east to west over the day-night cycle. A radiation experiment to evaluate the energetic particle environment will employ either an ionization chamber or geiger counters. These data from the radiation experiments are to be correlated with those from the vector magnetometer.

The full assemblage of experiments discussed above cannot be carried due to weight limitations. It is recommended that the experiments most directly supporting the manned landing effort be given first priority in the final selection. Although all the experiments mentioned are considered to contribute to the knowledge of the lunar environment and, hence, support the manned landing effort, the experiments which provide the most critical data are the TV experiment, the various measurements of hardness and surface structure, the radiation detectors and magnetometer, and the atmospheric pressure gage. In view of the criticality of the knowledge of the radiation environment, consideration of additional, more sophisticated, radiation experiments is recommended.

It should be pointed out that recently approved additions have resulted in the scheduling of three Surveyor firings in time to provide data prior to the February, 1964, manned spacecraft design freeze date.

LOCATION, EVALUATION AND SELECTION OF LANDING SITES

Location, evaluation and selection of landing sites for the manned mission is to be performed by the Surveyor A and B (lander and orbiter) and the developmental Prospector spacecraft. Since the missions of neither the Surveyor B or Prospector have previously been defined it is intended that this portion of the study recommend missions and types of experiments to support the manned landing program.

Surveyor B project

The primary objective of the orbiter is to locate landing strips for the manned mission. The tangential landing maneuver selected by Space Task Group will require a 300 mile by 10 mile strip, free of vertical obstructions of greater than 50 foot elevation. Such a site cannot be identified by a landed Surveyor since the 50-foot obstructions would not be visible at distances greater than 7 miles from a camera mounted 10 feet above a spherical lunar surface. The areas which seem the most likely to contain such a site are Oceanus Procellarum, Mare Nubium, Mare Tranquillitatis, and Mare Fecundilatis. A secondary objective of a reconnaissance satellite should be to provide data on the general topography to serve as a basis for extrapolation of data from lander experiments. Stereo coverage, possibly provided by overlapping frames, is desirable. Although complete lunar mapping is desirable, the mechanization of the reconnaissance system for the orbiter must emphasize the landing strip information.

A lunar orbiter is an excellent vehicle for fields and particles experiments. A three-axis magnetometer with a short rise time and moderately high data rate (extremely low compared with that required for the reconnaissance equipment) would provide valuable data on transient phenomena. The particle detectors should include plasma probes and high energy particle detectors for measurement of the intensity, energy and direction of the particle flux. The particles experiments could be supplemented with x-ray and gamm-ray spectrometers to distinguish between primary radiation incident on the moon and secondary radiation or natural radiation from the lunar surface. The correlation of data from the lunar satellite-borne fields and particles experiment with those from the surface-landed experiments could provide a basis for the understanding of the mechanism of transport of particles in the vicinity of the moon. Understanding of this mechanism is essential to accurate, long-term radiation hazard assessment.

It should be noted that the perturbations of the Surveyor B orbiter will provide data on selenodesy, of value in the study of return trajectories.

In order to support the manned landing program it is recommended that the Surveyor lunar orbiter be programmed to provide two firings as early as possible in 1964. A total of 23 Surveyor firings, including both the landers and orbiters, is currently scheduled from mid-CY 1963 through the end of 1967. After the first five Surveyor A firings the orbiters and landers should be programmed as needed. Some major experiments for the landers such as lunar sample return and small mobile physical parameters packs, which may be of extensive value to the manned program, are now under study and will be programmed at the earliest realistic date. These experiments are not to affect the overall Surveyor schedule.

Prospector project

The Prospector is currently conceived as a transport spacecraft capable of soft-landing about 3 tons of payload on the moon (if the C-3 is the launch vehicle). This landing craft would be suitable for three types of lunar missions for the location, evaluation, and selection of landing sites. A hovering mission with multiple landings for surface experiments, the landing of a sample or experiment return system on the moon, and the landing of a roving vehicle on the lunar surface.

The basic landing craft is to contain all subsystems required for the earth-moon transit and lunar operation, including vernier engines for controlled landing, but is to utilize a separable deboost stage for the major velocity decrement. (Use of the return propulsion system of the manned lander is attractive since such application puts operational time on that stage.) The landing craft is to have the capability of earth-controlled approach and landing point selection with TV monitoring. All Prospector spacecraft should carry long life radio landing aids to assist other Prospectors and manned craft, and a relay system for location of, and communication with, roving vehicles in line of sight. The landing craft should be fitted with attachments for an assortment of cislunar and surface experiments, probably selected from the Surveyor inventory. The total complement of experiments considered for Surveyor A would weigh about 500 lbs. and thus would constitute only a small portion of

the Prospector payload. The large landing weight of Prospector greatly reduces the effect of experiment integration on spacecraft design. The design of the landing craft should allow for utilization of the remaining three to four tons of payload for propellant for hovering and multiple landings at widely separated locations in the maria. Hovering at 100,000 feet would permit location of obstructions over a 200-mile radius on the surface.

A return system is recommended for evaluation of samples of the landing site material and for return of biological specimens transported to the moon for determination of the biological effects of the measured lunar environment. It is recommended that two types of return systems be considered in the Prospector design studies, one for return of several small experiments, the other for the return of the largest feasible single experiment.

Another payload recommended for Prospector is a roving vehicle or surface craft. This roving vehicle might be considered a surface counterpart of the spacecraft. It should be equipped with its own subsystems for communications, etc., and should be controlled from earth using the TV monitor. The surface craft should also be fitted with radio landing aids for other Prospectors, or the manned craft, and should be capable of carrying surface experiments of the Surveyor type, as well as the multiple unit return systems.

It is recommended that Prospector be programmed in such a way as to make the return system available after the first two developmental flights, and the roving vehicle available after the first four flights.

OPERATIONAL SUPPORT OF MANNED LUNAR EXPLORATION

Prospector project

The Prospector spacecraft and lunar surface craft will support manned lunar exploration by varied combinations of missions.

The Prospector spacecraft, with earth-controlled landing capability, should greatly reduce the hazard of lunar exploration by transporting life support materials and operational equipment (parts and test sets) to the landing site, both prior to and after the manned landing. Both the spacecraft and roving vehicle can be used to implace landing aids and TV monitors at critical positions relative to the manned landing point. The roving vehicle will be of further value for detailed study and, conceivably, limited physical preparation of the landing site.

It must be remembered that the ultimate reason for placing a man on the moon is lunar exploration. The surface transportation, portable communications, and TV monitoring provided by the Prospector surface craft are essential to manned lunar exploration. Thus, it follows that the roving vehicle must be suitable for manual as well as remote control from earth or other spacecraft.

As mentioned in the preceding section, the roving vehicle should be programmed for possible use on developmental Prospectors. No specific recommendations for other operational support payloads woll be made at this time, since their definition must be based on progress in the manned spacecraft development; the possibilities are innumerable. Let it suffice to say that there will definitely be a need for a proven cargo-carrying spacecraft launched with a quickly-prepared booster and having earth-controlled precision landing capability. Prospector will be this cargo-carrying spacecraft.

SUMMARY OF RECOMMENDATIONS

The recommendations resulting from this study of the space science contributions to the manned lunar landing effort are summarized on the following pages. The recommended flight program is presented in the accompanying figures, E-3, E-4, and E-5. The increased level of effort and reprogramming needed to support the manned lunar landing in 1967 is readily apparent.

S-3 (Radiation belt satellites)

Three additional S-3 satellites are recommended to provide adequate back-up and continuous monitoring until the EGO flights start in 1963.

EGO (Eccentric geophysical observatories)

Two additional spacecraft and launch vehicles are recommended to back-up the first EGO throughout 1964. Thereafter, it is recommended that EGO be on six-month centers rather than the one per year provided by the 10 year plan.

S-16 (OSO - Orbiting solar observatories)

Two additional spacecraft and launch vehicles are recommended to fill the $1\frac{1}{2}$ year gap of the present schedule during 1962 and 1963. Thereafter, OSO spacecraft should be launched on six-month centers instead of the one per year provided by the 10 year plan.

Sounding rockets

1. A standby operation at Fort Churchill is recommended for launching recoverable emulsion payloads when solar flares occur (up to 12 Nike-Cajuns per year).

2. Four Journeyman (ARGO D-8) sounding rockets with recoverable emulsion payloads are recommended for studies of the inner belt. (PMR launchings)

Recoverable satellites

One successful 4,000 to 5,000 n. mi. recoverable satellite per year starting in 1964 is recommended for studies of the inner radiation belt.

Solar flare prediction

Intensification of existing GSFC program as described in the main body of the text is recommended.

Figure E-3

Space Science Flight Program (I)

Projects	Objectives	1961	1962	1963	1964	1965	1966	1967
Geophysical and Solar Studies								
Earth satellites								
S-3 type	Radiation belt and magnetic field studies	▼○	▼○	○				
EGO	Above plus extended geophysical environment studies			▼○○	○	○	○	○
OSO	Solar electromagnetic radiation studies and monitoring	▼	▼ ○	○ ▼	○	○	○	○
Sounding rockets								
Solar flare standby	Detailed studies of proton bursts from solar flares	← 12 per year ○ →						
Journeyman (ARGO D-8)	Detailed studies of inner belt radiation in region not covered by satellites	← 4 per year ○ →						
Recoverable experiments								
Modified Mercury capsules	Bio-specimens and emulsions inner belt radiation		○○○					
4,000-5,000 nm satellites	Inner belt studies in region not covered by satellites			○○○	○○	○	○	○

Legend:

▼ Present schedule
○ Recommended additions

CONFIDENTIAL

<u>Ranger 1 and 2 follow-on</u>

The addition of two Ranger type spacecraft launchings in early FY 1964 is recommended to fill a large gap in the otherwise almost continuous monitoring of the deep space environment.

<u>Ranger 3, 4, and 5 follow-on</u>

The additional four approved flights should be directed toward high-resolution TV examination of the lunar surface and penetrometer experiments for hardness measurements.

All four of the add-ons should carry fields and particles experiments.

A lunar orbiter for fields and particles experiments should be considered for firing in FY 1963.

<u>Surveyor A</u>

Final selection of Surveyor experiments should emphasize support of the manned lunar program.

Surveyor A fields and particles experiments should be reviewed emphasizing the study of the hazard aspect of lunar radiation environment.

The Surveyor A sample return and mobile physical parameters package should continue to be developed and programmed for use as soon as possible.

CONFIDENTIAL

Figure E-4

Space Science Flight Program (II)

Projects	Objectives	Flight Schedule (CY) 1961	1962	1963	1964	1965	1966	1967
Deep Space Environmental Studies								
Ranger A (1,2,10,11)	Energetic particles Magnetic fields	▼▼		○○				
Mariner A & B *	Micrometeorites		▼▼		▼▼▼▼	○▼○	●	●●●●
Unmanned Lunar Exploration								
Ranger B (capsules, impacts)	Surface hardness and body properties Limited topographic data Radiation environment		▼▼▼●	●●●				
Surveyor A (lander)	Surface topography Physical properties Chemistry Mineralogy Radiation environment			▼●●	▼▼			

*Part of planetary program; funded separately

Legend:

▼ Missions included in establishing the original FY 1962 budget estimates
● Missions included in the revised FY 1962 budget estimates
○ Missions recommended as a result of this study

CONFIDENTIAL

Surveyor B

The objective of the lunar orbiter should be the location of landing sites. Secondary objectives should be complete lunar mapping, with emphasis on the maria regions, and fields and particles experiments.

The first orbiters should be flown as early as possible in 1964.

Prospector

RFP's for Prospector should be initiated as soon as possible. During the next year primary effort should be placed on the design of the cargo-carrying spacecraft with hovering and multiple landing capability controlled from earth with TV monitoring.

Design studies for the Prospector major experiments, return systems and roving vehicles, should be withheld until adequate definition of the lunar surface characteristics has been achieved and the contract for the spacecraft has been awarded.

The Prospector roving vehicle should be a surface transport craft capable of operation independent of the spacecraft, and suitable for transporting experiments, including small sample return systems, and man.

Figure E-5

Space Science Flight Program (III)

Projects	Objectives	Flight Schedule (CY) 1961	1962	1963	1964	1965	1966	1967
Location, Evaluation, and Selection of Landing Sites								
Surveyor A and B (lander, orbiter)	High altitude reconnaissance Radiation survey Surface topography Physical properties Chemistry Mineralogy				●●●	●▼▼▼●	▼▼●▼●	▼▼●●●
Prospector (hovercraft, roving vehicles, and earth return systems)	Low altitude and surface TV reconnaissance Selected experiments					●●	●●▼	
Operational Support of Manned Exploration								
Prospector	Landing site checks Landing aids and TV coverage Surface transportation Material support							▼▼▼

Legend:

- ▼ Missions included in establishing the original FY 1962 budget estimates
- ● Missions included in the revised FY 1962 budget estimates
- ○ Missions recommended as a result of this study

CONFIDENTIAL

SECTION E

Appendix I

THE RADIATION HAZARD

This Appendix briefly discusses the three major space radiation phenomena and the hazard presented by each.

Solar proton events.

Data obtained during the last solar cycle indicate that these events correlate well with sunspot numbers. The occurrence of these events should be at a low rate during 1963-1966, the interval predicted for the next minimum in the cycle of solar activity. Following this interval it is expected that the frequency of solar flares will increase, reaching a maximum around 1969 or 1970.

These solar particle beams have been observed using ground level monitors, balloon-borne counters, and nuclear emulsions and counters in rockets, satellites and space probes. The energies of the particles lie within a steep spectrum extending from $\sim$2-3 mev up to greater than 500 mev. Because of the frequent energetic proton emission by the sun during times of high solar activity, these particles were present in detectable intensity near the top of the earth's atmosphere for about 15% of the time from 1957 to 1960. The number of large flares that accelerated and released the particles during this three year period was about 30. Some of these events gave rise to such a high intensity of protons in the neighborhood of the earth that this phenomenon was recognized as a major radiation hazard to manned space flight.

The flux of protons with kinetic energies greater than 75 mev, range greater than 5 gm/cm^2, in these solar beams varies from about 20 times the normal cosmic-ray intensity to about 350 times. Because the flux of solar beam particles rises steeply at lower energies, the dosage which a man would receive rises rapidly as the thickness of his shielding is decreased. With 8 gm/cm^2 of shielding a man would have received an integrated dosage of from 2 to 200 rems for these events. The effects of shielding for a typically large event are shown in Table I.

TABLE I

Relative Dosage in Typical Solar Beams

Shielding (gm/cm^2)	Relative Dosage
2	2700
4	550
8	100
12	39
16	21
20	12

The permitted maximum emergency dosage for radiation workers is 25 rem. From a study of the riometer records and a comparison with balloon data at the University of Minnesota roughly 20 to 40 percent of the solar beams detected in the past would have given more than the maximum allowable dosage to a man shielded by 8 gm/cm^2. Hence, the probability of exposing a man behind such a shield to a beam which will give him a dangerous dosage is only about 1/3 that of exposing him to a solar beam of sufficient intensity to be detected on the earth.

Solar particle events, as observed at the earth, can be roughly categorized into two classes, those in which "direct" particles are detected and those for which "indirect" particles are detected. An example of the former is the event of 28 August 1958, and an example of the latter is the event of 3 September 1960. "Direct" particles are those which appear to come from a specific direction in space and are identified by their anisotropic arrival at the earth. "Indirect" particles are those which appear to arrive isotropically, i.e., equally from all directions in space.

The solar particle beams which have been observed differ widely in their characteristics and it is very difficult to generalize. However, the phenomenological behavior of a solar particle beam can be described very roughly as follows. The "direct" radiation, if it is present, arrives at the earth, following the solar flare to which it is attributed, in times

commensurate with the sun-to-earth travel times of the particles. This "direct" phase of the event is quite short (1-2 hrs.). There is then a transition period to "indirect" (isotropic) radiation and the event decays in much the same way as for events in which only "indirect" particles are observed. In events in which only "indirect" particles are observed, the time to maximum intensity is delayed, and this time delay varies from event to event. For example, in the event of 3 September 1960, the maximum intensity measured by the Deep River neutron monitor occurred about eight hours after the solar flare to which the event is attributed. The maximum intensity of protons with kinetic energies greater than 100 mev, as determined by balloon-borne detectors, occurred about 10-12 hours after the flare, and the maximum intensity recorded by the riometer at College occurred about 24 hours after the flare. In this event, then, there appears to be progressively later arrival of lower energy particles; the shape of the energy spectrum becomes steeper as the event progresses because the intensity of the higher energy particles begins to decline while the intensity of the low energy particles is still increasing. This behavior also appears in the large flare of 12 November 1960.

Closer examination of many of these events seems to indicate that the presence or absence of a "direct" phase is closely related to the condition of the interplanetary magnetic fields. Preliminary evidence suggests that some of the larger events have occurred at a time when a large gas cloud from a major flare was in the vicinity of the earth. This in effect provided a radial field connecting the earth to the sun. Since the solar proton events commonly occur in large active centers, the occurrence of a major flare some 24 hours preceding the event is not uncommon. Further study of the interplanetary magnetic field and its variations with time and solar activity is urgently needed.

Proton events are observed to follow the onset of large solar flares, usually of class 3 or 4, within 15 to 300 minutes. The proton event can be regarded as a part of the flare phenomenon. It appears that approximately 25% of the class 3 and 3+ flares are observed to produce protons. Because of the hazard to space travel, it becomes necessary to attempt to anticipate the occurrence of large solar proton-producing flares.

Flares occur in so-called "active regions" in the sun's atmosphere. These regions ordinarily consist of a more or less complex sunspot group with an overlying "plage", a bright region usually observed in the light of ionized calcium. They commonly contain large and complex magnetic fields, and often produce bursts of radio noise. Often there is brightening of the sun's outer atmosphere, or corona, over the active regions. Data on plages, radio noise bursts, the corona, and even on flares themselves is much harder to obtain and much more incomplete than for sunspot areas, especially in the years before 1957, the start of the International Geophysical Year. However, there have been some preliminary investigations of plage area and brightness, activity (rate of flare production) and age of active regions in relation to production of proton beams. These studies indicate that the large flares which produce proton fluxes occur predominantly in active regions having lifetimes of at least one week, and particularly in those containing fairly complex sunspot groups. (Here complexity means that the number of spots in the group is fairly great, the size of at least a few of the spots is large, a considerable amount of penumbra surrounds some of the spots, and the increase in the number of the spots has been fairly rapid.)

Of the approximately 40 solar proton events since January 1, 1957, seven stand apart as being by far the most intense, considering not only the peak intensities but the duration of the event as well. The parent flares in these cases occurred on July 7, 1958; May 10, 1959; July 10, 14 and 16, 1959; and November 12 and 15, 1960. Noticeable in the active regions connected with these flares is the large penumbral regions surrounding some of the sunspots. The area of these regions had become large even when, in the case of the July 1958 group, the age of the group was only two days. In the other three cases very large penumbral areas were present when the developing groups appeared on the east limb. On examination of several of the sunspot groups in active regions which gave rise to flares generating less intense proton fluxes, it was found that these were also characterized by early development of large, unbroken penumbral areas. The penumbral feature of active sunspot groups, therefore, seems at first glance, to provide a basis for anticipating when large flares will occur. The results of applying this method

over one and one-half solar cycles are shown in Table 5 of NASA TN-0-700. While the prediction of safe periods is fairly trustworthy over the last maximum, the reliability is not as good during the solar maximum in the late 1940's. However, in general the size of the events occurring during this period cannot be estimated since ionosonde data were used.

Clearly it is necessary to make a detailed study of the many other phenomena connected with active areas on the sun. Such a study would be greatly facilitated in the future by improvements in solar observations. Complete twenty-four-hour surveillance is essential as well as improvement of existing techniques and development of new ones.

Van Allen radiation belts.

These are generally considered in terms of two regions of differing characteristics. The inner belt is thought to be fairly stable with time. It appears to be predominantly protons concentrated at about 2,000 miles from the earth. The outer belt appears to undergo changes associated with magnetic storms and has been shown to contain electrons. The outer belt of electrons actually extends through the region of the inner belt, but it is usually considered to be centered about 13,000 miles from the earth. It's outermost boundary has been found to vary from about 20,000 miles to over 40,000 miles from the earth. Neither the origin nor the cause of the observed changes of intensity of the electron belt have been explained. A definitive measure of the electron flux in the inner and outer zones must await measurements of the electron spectrum. A flux value of 10^8 electrons cm^{-2} sec^{-1} above 20 kev is consistent with nearly all of the measurements that have been made so far.

The distribution of protons by number and their energy spectrum in the inner belt has been found to be a strong function of both altitude and longitude. For instance, the contour formed by a proton flux of 100 protons cm^{-2} sec^{-1} (protons above 40 ev) for the lower extent of the belt varies in altitude from about 570 km to about 1530 km. Protons can just be detected above normal cosmic ray background at altitudes of about 240 km less than the figures above. The asymmetry is because the earth's spin axis and the magnetic axis do not coincide.

The radiation levels to be expected from trapped corpuscular radiation are not well known and would constitute a problem for certain orbits. In particular, the radiation exposure that would be encountered during abort escape and return-to-earth maneuvers in which appreciable lengths of time might be spent in the belts should be assessed.

Galactic Cosmic Rays

Cosmic radiation consists of atomic nuclei moving with velocities near or in the relativistic velocity range. The principal constituent is protons, and next most abundant is helium nuclei (alpha particles). Smaller numbers of heavier atomic nuclei (to atomic number as high as 30) have been detected. Since these particles are electrically charged, their paths are bent by magnetic fields. The geomagnetic field prevents these particles from reaching the earth, especially at lowlatitudes. It has been found that the cosmic radiation with energy below about 5 bev varies with the solar cycle. At times of a maximum in the solar activity cycle this lower energy component is less than at solar minimum.

The biomedical effects and the flux of these low energy heavy galactic cosmic rays are not known. The uncertainties make further studies necessary on an urgent basis.

Summary of Principal Problems in Radiation Hazard Area

The previous section gave a broad, general introduction to the principal problem areas of the radiation hazards of space travel and of the recommended program for an increased level of investigation. These areas requiring further study can be summarized as follows:

1. A complete knowledge of the intensity, energy spectra, and charge spectra of various events is required in order to evaluate properly the potential hazard and to carry out meaningful shielding calculations.

2. A study of the isotropy of various events and the relationship of isotropy and intensity to the state of the interplanetary magnetic field is necessary. This may be the crucial step in developing a prediction capability for big events.

3. The physics of solar flares is not well understood. A thorough knowledge of this phenomena is necessary before there is any possibility of establishing a proper prediction criteria.

4. A more detailed knowledge of the intensity and spectra of the Van Allen radiation belt is required. In addition, the charge and energy spectra of low energy galactic cosmic rays should be determined and their biological effects should be more accurately assessed.

SECTION E

Appendix II

COMMENTS ON AN EARLY LUNAR ORBITER

Throughout this study it has been apparent that lunar orbiters are extremely desirable for the investigation of the radiation hazard to be encountered during manned lunar flight. Although the extensive fields and particles experiments have been recommended for the Surveyor B lunar orbiter in 1964, there is a definite need for an earlier lunar orbiter during periods of high solar activity. Such an orbiter has not been included in the recommended program due to controversy concerning the relative priority, appropriate time phasing, and proper spacecraft and launch vehicle for such a mission. It is the recommendation of the study group that an early lunar orbiter be considered by the Office of Space Flight Programs and the Space Sciences Steering Committee.

The Goddard Space Flight Center has been active in advancing their recommendation on solar radiation monitoring. Their position is well conveyed by the attached copy of a memorandum by the Director of Goddard Space Flight Center of June 13, 1961. This memo is included here to present the GSFC position, and does not represent a recommendation of the authors of this report.

June 13, 1961

MEMORANDUM for W. A. Fleming
A. M. Rothrock

Subject: Solar Radiation Monitor

It is the purpose of this memorandum to restate to you the case I made verbally in our intermission discussion last Saturday relative to "solar radiation monitor" which is not provided for in the present manned landing program. It appeared that we were in agreement in principle with this need. However, it is my concern that the present plan is likely to be completed without provision for the spacecraft, vehicle and funds required for such a monitor. Despite assurances that the plan is not frozen, past experience indicates that it is difficult to change a plan once it is formalized. I therefore hope the following persuades you to make provision for this solar radiation monitor in the initial plan.

The present plan includes some S-3 and OGO-type satellites in moderately elliptical orbits, with apogees of approximately 50,000 miles. These satellites will serve to monitor the radiation belts. However, a possibly greater need is the monitoring of the effects of major solar events in the region outside the influence of the earth's magnetic field, i.e. 20 earth radii or more from the earth. This need arises from two sources:

(a) There is some reason to believe that a major event, characterized by the emission of energetic protons by the sun and their subsequent arrival in the vicinity of the earth only occurs after a previous lesser event which has modified the sun's magnetic field in such a manner as to form an effective "pathway" for the particles emitted by the succeeding event. Thus, the detection of this change in the sun's magnetic field between the earth and the moon could conceivably act to warn that the conditions favorable for a major solar event were in existence. To detect these interplanetary magnetic field changes it is necessary to be outside the influence of the earth's magnetic field (i.e. 20 earth radii or more out).

(b) A second question that must be studied is the directionality of the energetic particles emitted by the sun during a solar event. Once again this must be done outside the influence of the earth's field which modifies the directions of the particles, probably making them more omni-directional. If it turns out that the particles in these major events come uniformly from one direction, this fact can be used to reduce the weight of the spacecraft radiation shielding.

The present plan does not include spacecraft specifically designed for the above purpose. The S-3 and OGO types do not go far enough out, as previously stated; the Mariner probes get too far out. What is needed is a very high altitude (150,000 mile or more) circular earth orbit, an eccentric earth orbit with an apogee greater than 250,000 miles, or a lunar orbit which in effect uses the moon as a space "anchor." Of the three approaches, the lunar orbit would be preferable as it would give the radiation environment of most interest to Apollo, that near the moon. Specifically, an "Atlas-Able-5 type" of spin stabilized spacecraft could serve the purpose by injecting into the required lunar orbit. Alternatively, the injection of a payload from the Ranger "bus" is a possibility. (JPL is in a better position to assess the relative merits of these two approaches than we are.) Calculations indicate that a 3,000 mile lunar orbit would be a reasonably stable one, and would be sufficiently far out to be free of influence of the lunar magnetic field, if any.

The instrumentation on board this vehicle should be in effect a combination of P-14 and S-3 instrumentation. There should be a rubidium magnetometer for drift free measurement of the absolute magnitude of the magnetic field, two flux-gate magnetometers for measurement of the direction of the field, a plasma probe, and energetic particle sensing instruments with capability of measuring direction of the particle flow. It is believed this instrumentation could be readily adapted to the Atlas-Able 5 spacecraft, telemetry, etc; a boom would have to be installed for the magnetometer. This spacecraft already incorporates a hydrazine motor for injection into the lunar orbit. For the alternative of injection from the Ranger bus the payload could essentially be a combination of the present S-3 and P-14 payloads with solar paddles added and suitable modifications of the telemetry for the increased communication distances.

CONFIDENTIAL

The foregoing implies that the plan should provide for such a "solar radiation monitor" continuously in orbit. Prior to the manned lunar launch date it would serve to provide the desired understanding of characteristics of solar events. If these earlier flights support the hypothesis that major solar proton events are preceded by solar magnetic field changes, the monitor would be used at the time of the manned lunar launch to indicate when conditions were favorable. One of the reasons I am persistent in making this point is the fact that it will require a considerable increase in the lunar program, and thus perhaps a significant reallocation of funds from other portions of the programs.

This proposal to a degree crosses "mission lines" as between Goddard and JPL, since JPL is responsible for lunar spacecraft. Goddard would hope to be importantly involved in the instrumentation since it derives so directly from P-14 and S-3 types on which we have or will get experience. Also, this "solar radiation monitor" should be treated as one part of a total solar radiation study program which includes ground observations, observations of the radiation belts from S-3 and OGO type satellites, and observations of the sun itself from Orbiting Solar Observatories. We would hope to operate as coordinator of this total solar radiation program, and as "system" manager of the payload under JPL's project management of the lunar orbiting project.

I have discussed this matter with Dr. Pickering and will send him a copy of this memorandum for consideration with respect to future Ranger missions, and for study of feasibility from the spacecraft standpoint.

/s/ Harry J. Goett

Harry J. Goett
Director

C
O
P
Y

CONFIDENTIAL

CONFIDENTIAL

PART II

SECTION F

ADVANCED TECHNOLOGY PROGRAM

FOR

EARLY MANNED LUNAR LANDING

E. O. PEARSON
OFFICE OF ADVANCED RESEARCH PROGRAMS
NASA

JUNE 16, 1961

CONFIDENTIAL

ADVANCED TECHNOLOGY

Summary and General Remarks

The manned lunar landing program because of its highly advanced nature will depend critically for its timely success on a strong research and advanced technology program covering many areas. It is necessary therefore to bring the best available technological competence and research talent in depth and variety both in-and out of house to bear on the problems.

It is further highly important to expand and extend present programs and to provide needed facilities at the earliest possible time to insure that adequate basic information is available for the soundest possible spacecraft, launch vehicle, and systems design.

There will be instances in the development program in which calculated risks will probably have to be taken in the face of insufficient design information. If this occurs on an extensive scale, however, there will most assuredly be redesigns, lost motion, and delays.

In figure 1 are listed some of the most important problem areas presently foreseen. These are discussed in some detail in the body of this section. The situation with respect to a few of the more critical of these is summarized in the following paragraphs:

Reentry Heating, Structures and Materials, Aerodynamics--The immediate goals of the present accelerated program on reentry problems are to reduce the uncertainty surrounding the radiative heat transfer at lunar return speed, to establish as firmly as possible the ability to shield against the combined radiative and convective heating, and to provide a broad base of information on the flight characteristics of a number of suitable spacecraft configurations to permit a sound choice of configuration for Apollo.

Selection of the reentry configuration will permit concentration of effort on specific design problems--dynamic stability, controls for trim and damping, heat shield shape to minimize heating, heat shield material performance, and others. Confidence in ability to deal with heating will rise with time but will not be completely assured until Atlas-Agena reentry flight tests are conducted.

PROBLEM AREAS OF IMPORTANCE

Spacecraft Technology

1. Reentry Heating, Structure, Aerodynamics
2. Midcourse Navigation, Guidance, and Control
3. Radiation and Shielding
4. Reentry Guidance and Control
5. Mission Abort
6. Earth Landing
7. Artificial Gravity
8. Micrometeoroid Environment and Impact Damage
9. Vacuum and Thermal Radiation Effects
10. Data Handling and Communications
11. Lunar Landing

Launch Vehicle Technology

12. Vehicle Design, Structural Dynamics, and Control
13. Injection Guidance
14. Noise
15. Propulsion

Figure 1

Navigation, Guidance, and Control--Injection guidance technology is probably on firmest footing of all elements of the guidance problem, but improved accuracy and reliability are needed. Possible use of manned control during launch and injection to assist overall mission reliability should be seriously studied.

In mid-course guidance and navigation there are problems of determination of position and velocity in space with extreme precision and of the best means of correcting errors. At present we depend on instruments, such as star trackers, inherited from other missions. The adequacy of various possible systems for space navigation has not been demonstrated or investigated under conditions of adequate simulation. Instrument needs are not yet well defined. Reentry guidance is in essentially the same situation.

The integration of injection, mid-course, and reentry guidance systems has had little if any serious study.

Radiation and Shielding--Despite a broad background of fundamental scientific knowledge in high-energy radiation physics there is a large area involving the effects of radiation on materials and components and shielding against charged particle radiation in which detailed knowledge is absent. Some of the needs are as follows:

a. Study of shielding materials, with particular reference to the effectiveness and resistance to radiation damage of material employed for composite spacecraft shielding design.

b. Study of inorganic materials, such as ablative heat shields, seals, lubricants, glasses.

c. Study of change in surface characteristics such as emissivity, important to thermal control.

d. Study of secondary radiation behind materials used for shielding.

e. Study of degradation of performance of solar cells, transistors, infrared detectors, masers, and assemblies subjected to radiation.

f. Study of electrostatic and electromagnetic shielding.

Lunar Landing--The whole question of manned lunar landing is open to discovery and invention. We are faced essentially with the problem of landing in a hostile environment on an unprepared and imperfectly-known surface, with complete reliance on power and without passive means of escape such as an atmosphere provides, and with the ever-present possibility that slight damage to the vehicle that would be inconsequential on earth might remove all possibility of the return flight.

We need to study techniques, guidance and control instruments and systems, ability of man to control landing and takeoff operation, system dynamics, jet-created debris, landing impact and space vehicle design for resistance to landing impact damage. Intensive work is needed merely to identify and define the important problems.

Launch Vehicle Design, Structural Dynamics, and Control--This overall area represents one of the largest requirements for design information related to the efficient and reliable structural design of large light-weight, highly loaded, flexible, aerodynamically unstable vehicles. The needs include:

a. Definition of wind shear structure of the atmosphere.
b. Extensive measurements of in-flight loads on current vehicles.
c. Fundamental data on aerodynamic forces, fuel sloshing, structural modes, frequencies and damping, and control system characteristics.

Noise and Explosion Hazards--Basic problems are:

a. Problem associated with site selection for launch and test of Nova vehicles; and continuing problem in dealing with hazards of their operation.
b. Vehicle and spacecraft design for operation in an intense noise environment.
c. Launch pad abort in event of explosion.

Biggest unknown in the noise problem is in the effects on structures of all kinds, including the vehicle, of intense noise at low frequencies in the range of 1 to 50 cycles per second.

Attention is invited to the final part of this section describing special facilities needed for study of the problems outlined. They are highly important to a sound development program and should be given serious consideration. For the most part they can be available in approximately one-year's time, with two or three of the more complex requiring $1\frac{1}{2}$ to 3 years to complete.

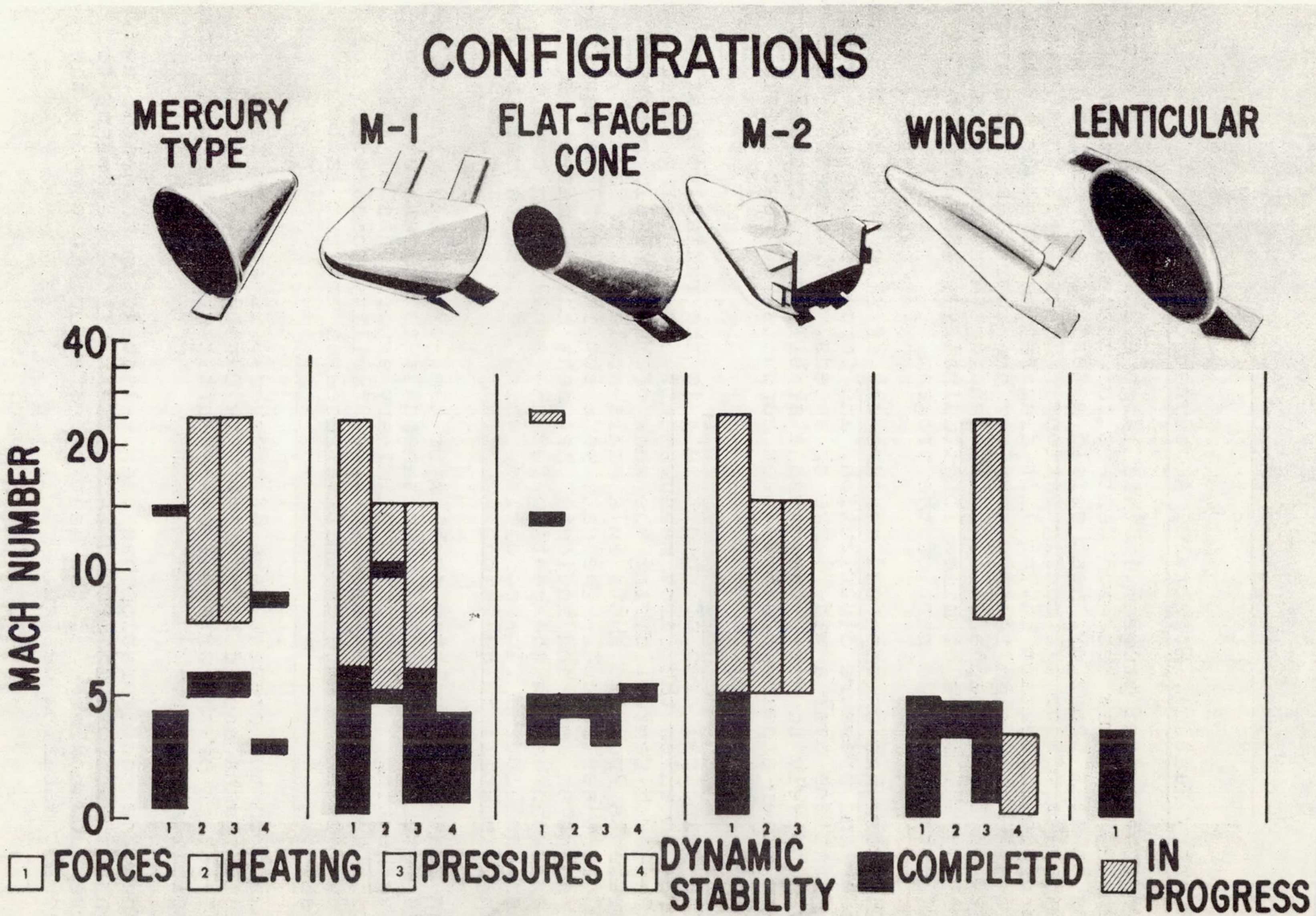


Figure 2

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER, MOFFETT FIELD, CALIFORNIA

ADVANCED TECHNOLOGY

1. <u>Reentry Heating, Structure, Aerodynamics</u>

An accelerated program in this large area has been in progress at Langley and Ames Research Centers for the past eight or nine months on heat transfer, heat shield materials and design, and aerodynamics of low L/D configurations. Emphasis is on a general class of configuration having lift-drag ratios of about ½ which permit a 40-mile high reentry corridor and appreciable maneuvering ability in the atmosphere for point landing (hundreds of miles laterally; thousands of miles longitudinally). See figure 2 for illustration of a part of the program.

The work has encompassed measurement of flow phenomena, heat transfer and pressure distribution, and forces for a variety of configurations over a wide range of speeds, and, somewhat less comprehensively to date, the dynamic stability and control. Arc-jet and other experiments have been conducted on heat shield materials.

The principal area of uncertainty is the radiative heat transfer on which the first measurements are now being taken. Ames Research Center, during the week of May 8, 1961, reported measurements from two shots in a small-scale pilot facility at 42,000 feet per second. The data were obtained for the equilibrium radiation case and indicate that heat shield materials available can handle the heating for the equilibrium condition. The non-equilibrium flow condition, which represents more severe heating, is still in question.

An additional related problem is that of the behavior of heat shield materials subjected simultaneously to radiative and convective heating. The first preliminary experiments on this question have just been made in a new facility constructed for this purpose and a more definitive research program is being started.

Based on the present rate of progress, it appears that sufficient data should be available by October, 1961, to permit the selection of the external spacecraft configuration on a sound technological basis.

When the configuration has been selected, an augmented and concentrated effort in ground facilities will be necessary to improve our knowledge of the heat transfer and to support the spacecraft detailed design.

A few of the specific problems requiring particular attention are as follows:

a. Continued study of heat shield materials subjected to radiative, convective, and chemical heating.

b. Heat shield shape to minimize combined radiative and convective heating.

c. Heat transfer to forebody and afterbody over range of spacecraft attitude.

d. Flight dynamic behavior in all speed regimes.

e. Aerodynamic and reaction controls for trim and damping.

f. Spacecraft structural design and insulation.

Finally, reentry flight tests are scheduled to confirm ground test results, particularly with regard to heat transfer and heat shield integrity. The program includes three Scout shots to 29,000 feet per second and four Atlas-Agena shots to 36,000 feet per second.

2. <u>Midcourse Navigation, Guidance, and Control</u>

Trajectory studies conceptual design of systems and techniques, many components, and human pilot control capabilities are areas in which work is well underway and which should be augmented in an accelerated space program. Some examples of recent work in these areas are (a) application of statistical methods for improved precision in the determination of position and velocity and in the application of corrective thrust, (b) study of accuracies of optical navigation techniques such as star triangulation, occultation of stars by the moon, measurement of subtended angles of earth and moon, (c) study of ability of a human operator standing on a moving platform to make precise sightings through a telescope mounted on a stabilized platform.

Needs are for analytical and experimental synthesis of complete systems (such a synthesis is being started using analog equipment), and for experimental study of instruments and components for precision navigation and guidance. A strong contractor effort is required backed up by a strengthened in-house capability.

In-house facility needs are treated at the end of the Advanced Technology section.

3. Radiation and Shielding

In addition to needs for knowledge of the space radiation environment and biological effects which are treated in another section, work is required on the design problems created by the radiation environment. Some of the areas in need of study are the secondary radiation behind spacecraft materials of various kinds, techniques of shielding for minimum weight and maximum effectiveness, and proper reproduction of the essential elements of the real environment in laboratory experimental facilities. Study is needed of the effects of high-energy particle radiation on spacecraft materials such as the heat shield and windows, and on components such as those of the guidance and communication systems. Incidents with satellite and probes of premature battery or solar cell failure and loss of communication have occurred which have been speculated to be due to energetic radiation. The total seriousness of the problem is not now known, but since the radiation is a fact to be contended with and designed for, its effects must be thoroughly explored and understood. A system or component failure traceable to this source may be only a disappointment in an unmanned spacecraft but could lead to disaster when men are involved.

Some beginning work has been done by Langley and others on effects of radiation on small electronic components making use of existing particle accelerators. Primary reliance for data in the early design phases of Apollo will probably have to be placed on use of existing accelerators in spite of limitations of the equipment and its availability.* A 600 Mev (maximum energy) proton

---

* There are seven accelerators in this country and Canada capable of producing proton beams with energies greater than 100 Mev, located at Columbia University, University of California at Berkeley, University of Chicago, University of Rochester, Carnegie Institute of Technology, Howard University, and McGill University. Limitations of the available facilities with regard to the needs of space technology arise principally from the small beam cross section, fixed energy levels, and difficulties in handling and instrumenting samples to be irradiated. All of the facilities are engaged in basic scientific research on a full-time basis, with the result that only small amounts of time from a few of these facilities have been available for engineering research of the kind required by the space program. AEC people have stated informally that if all pending tentative requests by NASA and DOD for test time in AEC-owned accelerators were acceded to 50% of the available time would be taken up by such programs.

accelerator designed specifically to serve space flight research and advanced technology purposes is proposed in the preliminary 1963 budget estimate and is needed in the development stages of the Apollo program to study radiation effects on material and the effectiveness of shielding arrangements for the men. Construction of the facility would take between 2 and 2½ years. If it were started in July 1961, it would be available in the latter half of 1963. It is recommended that this item be included in the FY 1962 budget request.

Engineering recoverable satellite flown through the Van Allen belts would provide additional data on radiation effects on material. Such experiments could possibly be combined with similar biological flights, and are tentatively planned on that basis.

4. Reentry Guidance and Control

A broad program is already underway in this area particularly with regard to pilot-controlled reentry, and will continue. Particular attention should be given to work that will define the best flight techniques and means of control, and to work on pilot presentations.

As in the case of the midcourse guidance problem there are needs for experimental work on instruments and other components which require contractor efforts and a properly supported in-house back up.

The problem of communication blackout during reentry is important but may not be critical. It may not be solvable. Ground and flight tests are being carried out and should be properly supported.

5. Mission Abort

Provision of the ability of the men to escape from the main propulsion will be just as critically important for Apollo as with Mercury and for the same reason. The Apollo abort problem is more difficult than with Mercury because of the need to be able to escape from the launch vehicle at speeds up to 36,000 feet per second and the need to be able to cut the flight into space short in the event, for example, of a sudden alert for a giant solar flare. Escape from the blast of a Nova vehicle explosion may prove to be a very difficult problem.

Analytical studies of the Apollo abort problem are being carried out at the Research Centers, Space Task Group, and the three Apollo study contractors. Continued and expanded efforts are needed to arrive at feasible solutions.

6. Earth Landing

Efforts are underway by STG on steerable parachute development, by Langley on the paraglider, and by both Centers on impact attenuation.

Technological efforts pertinent to parachute control, paraglider control, packaging and deployment and impact attenuation should be augmented (large scale tests) and should be continued as necessary in conjunction with hardware development.

7. Artificial Gravity

It is currently not known whether protracted weightlessness, coupled with the somewhat cramped quarters of the spacecraft, will seriously inhibit pilot performance. No plans exist for testing human performance, other than the 18-orbit (approximately 26 hours) missions in 1963, until manned orbital flights in 1965. The fourteen day animal flights in late 1962 and 1963 will provide partial answers.

It appears necessary, therefore, to initiate a program of conceptual and preliminary design of spacecraft which will provide artificial gravity. This recommendation is made in the section dealing with spacecraft development.

It is also possible that means to circumvent the potential need for artificial gravity could be devised (e.g., oscillating or vibrating couches). A combined engineering-medical study is proposed using best available knowledge of the nature of the physiological problems. Experiments with water submersion techniques might be meaningful and need objective study.

Initiation of programs to explore these alternate paths is recommended, with periodic review to determine the necessity of continuation or re-direction.

8. Micrometeoroid Environment and Impact Damage

Several aspects of the micrometeoroid problem need attention. A new dimension has been added to the Apollo problem in this regard with the inclusion of large propellant tanks in the spacecraft system required for lunar landing and take-off.

With regard to the micrometeoroid environment, the problem may resemble to some extent the situation with solar flares, in that a most dangerous time probably exists when the earth-moon system is passing through the tails of comets with larger than normal density of debris. To assist in enlarging our knowledge

of the meteoroid environment, particularly with respect to showers, a ground-based observation effort is proposed to augment the existing program of flight experiments. A radar observation network for measuring the altitude, speed, and direction of meteors of all sizes down to those too small to be seen has been set up by the Smithsonian Astrophysical Observatory. It is our understanding that this facility is not operating because of lack of operating funds. The data that could be provided are needed and it is recommended that NASA undertake to find or provide the financial support required which is understood to be modest.

The currently planned flight programs to study micrometeoroid flux and material penetration rates are very limited in scope and will not provide sufficient data for sound engineering design. Additional experiments are required to provide even rudimentary engineering design guides.

Another area of importance is that of laboratory research on impact damage. Current techniques for producing high particle velocities, based primarily on light-gas guns, have only recently produced speeds of around 30,000 feet per second which is about at the lower boundary of natural micrometeoroids. Further development of these techniques appears feasible and can perhaps lead to speeds in the range of 40,000 to 50,000 feet per second.

An electrostatic microparticle accelerator proposed in the preliminary FY 1963 budget estimates offers the possibility of achieving particle speeds as high as 80,000 feet per second and should be funded in FY 1962.

Efforts to determine effects of particle impace on cryogenic fuel tanks should be augmented if the spacecraft utilized cryogenics for lunar landing and/or takeoff.

9. <u>Vacuum and Thermal Radiation Effects</u>

The work done to date on the effects of hard vacuum and unattenuated solar thermal radiation on materials has been largely preliminary and has served primarily to demonstrate that important problems indeed do exist. For example, one recent experiment in which a sample of a proposed ablation heat shield material was exposed to hard vacuum showed that the specimen lost 50% of its weight in 12 hours of exposure.

The central need in attacking these environmental problems is that of providing a fairly large number and variety of specialized vacuum chambers, mostly in small sizes, with associated equipment and instrumentation.

10. Data Handling and Communications

The type and magnitude of data to be handled on board the vehicle must be determined. Once this is known, attention can be given to the matter of on-board data handling. This involves processing, display, storage, and transmission to and reception from earth of data concerning navigation and guidance, scientific measurements, crew conditions, and vehicle systems performance. Such links are vital to the success of the mission and to the evaluation of any failures.

The on-board problem is one of providing reliability through redundance and/or repair; processing to minimize extent of displayed, stored, and transmitted data; and systems with minimum weight, size, and power requirements. The design of vehicle borne antennas and transmitters and earth-based equipment must take into consideration the communication requirements for all phases of the mission: flight to the moon, lunar operations, and return flight. Vehicle antennas, particularly the directional equipment, require special consideration. They have to perform in the environment of space and thus require special attention to their erection, artic ulation and detection mechanisms.

11. Lunar Landing

The technological problems of letting down and landing on the moon and leaving safely constitute a special category which should perhaps have been singled out for separate and special treatment. The field is wide open for discovery and invention. It is highly probable that even with accelerated and expanded Ranger, Surveyor, and Prospector programs we will have only rudimentary knowledge of the surface and environment of the moon--something akin to spot checks. The spacecraft design for lunar landing will have to depend largely on information generated by a research and development program conducted on the earth. Contingencies will have to be allowed for which cannot now be foreseen.

Some of the basic uncertainties connected with the lunar landing problem, in addition to the lunar surface characteristics and environment, are approach and landing technique, guidance techniques and components, automatic versus manned control, jet-created debris, landing gear requirements and design, automatic stabilization in the presence of sloshing fuel and thrust vector wandering, thrust control, cryogenic propellant management.

A start has been made in several of the above-mentioned areas. An immediate expansion of in-house effort on the foreseeable problems and intensified study of the overall aspects to uncover potential problems are required. Important contributions can be expected from Surveyor and Prospector technology programs especially if they are tied in more closely to assist Apollo needs.

Model-scale flight experiments in the earth's atmosphere with automatic systems have been proposed and need careful consideration.

Special research facilities to study problems of piloting technique, guidance and control, landing impact, propulsion, attenuation of radio and radar waves by rocket exhaust, and dust cloud phenomena are needed and are proposed for early funding.

LAUNCH VEHICLE TECHNOLOGY

12. Vehicle Design, Structural Dynamics, and Control

Efficient design of launch vehicles of the size and weight necessary for the accomplishment of the manned lunar landing mission requires greatly increased knowledge of the characteristics of minimum weight, flexible, highly loaded structures. The effects of heating, atmospheric disturbances and discontinuities, aerodynamic and control forces all interact to result in an extremely complex design problem. This general area represents one of the largest requirements for design information. There is an immediate need for a large expansion of in-house and contractor effort.

The area of launch vehicle structural loads and dynamics has been a serious stumbling block in early space vehicle systems and recent reviews have indicated serious gaps in our knowledge and technology in this area. These problems become more serious and difficult with increasing vehicle size. A broad technological and research program is currently being developed and must be pushed vigorously with particular reference to very large vehicles. The program encompasses a number of significant elements which include:

Definition of the atmospheric wind and wind shear by means of atmospheric sounding programs.

Extensive flight loads measurements on contemporary vehicles.

Development and refinement of analytic technology in conjunction with flight loads measurements.

Development of ground based experimental techniques to provide fundamental data on aerodynamics, fuel sloshing, structural modes, shapes, frequencies and damping, and control system characteristics.

Development of structural testing and combined structural and aerodynamic testing techniques.

Stress analysis techniques of thin tank structures, including effects of concentrated loads, discontinuities and joints under static and dynamic loading conditions.

Control system--structural interaction problems involving sensor locations and dynamic structural response.

Some of the specific funding needs are for sounding rockets for measurement of the wind shear structure of the atmosphere, for instrumentation and equipment for the measurement of dynamic loads in flight on present vehicles, and for relatively large size dynamically scaled laboratory models of proposed Nova vehicles.

There are a number of special and important launch vehicle problems that are closely connected with specific vehicle designs. Two of these that may be mentioned are staging and stage separation in the atmosphere, and base heating. Work in these areas, both generalized and specific to most of the current vehicles, has been done at Lewis, Langley, and Marshall. No unusual needs are foreseen at this time other than that the programs in existence should be oriented toward Nova problems and accelerated.

With particular regard for vehicle stabilization and control, adaptive systems could conceivably improve launch vehicle structural reliability through widened tolerance to uncertainties. This must be properly weighed against problems of control system design and reliability.

Several relatively small projects aimed primarily at Saturn class vehicles, and largely analytical, are underway on adaptive systems. An adaptive control system has been constructed for the X-15 and is currently being installed in one of the machines for flight tests starting in late fall of 1961.

The effort on adaptive control systems and related techniques should be expanded and directed toward Nova vehicle application. Analytical and experimental work is needed.

13. <u>Injection Guidance</u>

Injection guidance technology, relatively speaking, is probably on the firmest footing of all the elements of the lunar navigation and guidance problem. Nevertheless improved accuracy and reliability are needed. Particular sub-areas of importance are inertial platform and digital computer technology and study of various modes of guidance. Serious study is needed of the extent to which injection, midcourse, and reentry guidance should or can be integrated into a common system. The possibility of manual control of launch and injection, either primary or back-up, has been advanced somewhat timidly by proponents on occasion and rejected out of hand by opponents. It should be seriously re-examined with a view to undertaking definitive work to assist in settling the questions.

Contractor and in-house work is required.

14. Noise

Two principal aspects of the noise problem with Nova class vehicles need careful attention, namely that of property and physiological damage and nuisance in areas surrounding test and launch facilities and the problem of vehicle structure and systems damage from the intense low frequency near-field noise.

The first mentioned aspect is the more pressing since site selection is involved. A preliminary study and evaluation of this problem was undertaken during course of the work of this task group and a preliminary report was prepared, the results of which are included elsewhere in this document. An independent guide review was also taken of the status of our knowledge of Nova noise. A short discussion on the subject is given in an appendix to the Advanced Technology section of this document.

Both of these preliminary efforts recommend an intensive follow-on study. Particular attention is needed in this follow-on study to obtain a thorough and complete study using the best available information.

The second aspect of the noise problem is essentially that of determining effects of intense low frequency noise on vehicle structure and systems. An addition to an existing noise research facility is proposed to permit generation of single frequency and random noise of high intensity in the frequency range from 1 to 50 cycles per second. This equipment could be available six months after go-ahead.

15. Propulsion

Many of the problems of importance in propulsion technology are associated with lunar landing and take-off propulsion (mentioned in general terms in the preceding paragraphs dealing with lunar landing problems) and more generally with propulsion systems that must operate in space. Some of the specific problems relate to thrust modulation, operation of small attitude control motors, pressurization and expulsion of propellants, insulation of propellant tanks, propulsion system-vehicle interactions. Facilities needed for study of these problems are included in a following section.

With reference to main launch vehicle propulsion, if a new large hydrogen engine is to be developed a critical item will be the required large hydrogen pump. Contingent on the decision on large engine development, an energetic research and technology program leading to pump development (including provision of a facility) will be required.

CONFIDENTIAL

Many individual components pertinent to propulsion and tank systems, such as valves, flanges, gaskets, and seals require effort toward achieving substantial improvement in reliability.

ADVANCED TECHNOLOGY

R&D Requirements

Engineering radiation effects recoverable satellites flown through radiation belts, including evaluation of effects on heat shield (based on shared program with similar biological experiments).

Instrumentation and equipment for in-flight measurement of dynamic loads on scheduled vehicle flights; large scale dynamically similar laboratory models of Nova vehicles.

Sounding rockets for wind shear measurement.

Contractor effort on launch vehicle stabilization and control.

MSFC and contractor effort on injection guidance.

Contractor effort on vehicle and systems noise damage.

Contractor effort on Nova-class vehicle design problems.

Air drop simulator to study component and system interaction for lunar landing study--3 configurations, 15 drops. Period of flights, 12-24 months from go-ahead.

Study of radiation shielding for Apollo. Analytical and experimental investigation of interactions of charged particles with nuclei to determine probability of interactions of secondary particles and their energies.

Radiation Damage Studies. Damage to materials at 10 mev to hundreds of mev.

Proton induced nuclear reactions.

Electromagnetic shielding study.

Lubrication and Wear Research Accelerated program on Apollo problems--using existing facilities.

High speed meteoroid impact study of brittle fracture of propellant tanks. Equipment includes expendable instrumentation, gun barrels, cryogenic valves, fracture specimen.

Satellite payload packages, 3 packages for determination of impact effects on brittle materials.

Improvement of reliability and weight reduction of cryogenic propellant tanks. Equipment for low-cycle bi-axial fatigue tests at cryogenic temperature. Fracture test equipment for study of weld degradation.

Detection devices and on-board damage data handling. Study of methods for detecting micrometeoroid damage. Foil gauges and data handling equipment.

Temperature distribution in space vehicles. Present facilities used to study temperature balance in models.

Meteoroid hazard and environment 3 payload packages.

Contract R&D study leading to design of radiation heater for Mass Transfer Facility for study of combined radiative-convective reentry heating.

ADVANCED TECHNOLOGY

Facility Requirements

Low-Frequency Environmental Noise Facility

This facility provides for a high-intensity low-frequency (1-50 cycles per second) noise source to be located at an existing noise facility at the Langley Research Center, to study the effects of characteristic Nova noise on vehicle structures and systems and effects on shelter structures. Estimated construction time is 6 months.

Space Radiation Effects Laboratory

This facility consists of two high-energy particle accelerators and associated equipment for simulation of radiation belt and solar flare environment. A diffuse-beam 600 mev proton accelerator is the principal item of equipment. The second and smaller accelerator is a 2-10 mev linear electron accelerator. The facility is needed for

a. Study of effectiveness and resistance to radiation damage of materials used in composite spacecraft shielding design.

b. Study of radiation effects on spacecraft materials, such as ablative heat shields, seals, lubricants, glasses, and effects on surface characteristics such as emmissivity.

c. Study of secondary radiation behind shielding materials.

d. Study of degradation of performance of solar cells, transistors, infrared detectors, masers, and assemblies.

e. Study of new shielding techniques such as electrostatic and electromagnetic shielding.

Construction time is estimated at 2 to 2½ years.

Additional Power Supply and Improved Arc Chamber for Existing 10 Megawatt Arc Tunnel

The Langley 10-megawatt arc tunnel is nearing completion and scheduled to operate shortly. It will be capable of stream enthalpies corresponding to reentry at satellite velocity. To study adequately the materials and structural problems of the Apollo reentry module higher stream enthalpies are required

approaching twice those for satellite reentry. The proposed equipment is to improve the ability of the existing facility to get data on heat shield performance and related structural problems of direct application to Apollo. Estimated time to initial operation 10 months.

Environmental Research Facilities for Spacecraft Components and Materials

This project consists of an array of small vacuum chambers (1 to 50 cubic feet) with associated equipment and instrumentation for the study of spacecraft materials and structural components subjected to hard vacuum and simulated thermal radiation. Approximately 40 vacuum chambers are needed in order to carry out simultaneously a large number of experiments, each of days, weeks, or months duration. The smaller, less complicated components of this facility can be procured and put into operation immediately. Facility is estimated to be completely equipped in 16 months.

Lunar Landing Test Facility

This facility consists of a large outdoor assembly involving an overhead track 200 feet high by 800 feet long supporting a powered carriage and winch system from which is suspended the independently powered manned test vehicle. Horizontal velocities up to 100 feet per second and vertical velocities up to 30 feet per second would be provided. Provision would be made for partial support of the weight of the test vehicle to simulate the moon's low gravitational field. This facility is urgently needed to study guidance and control, piloting technique, and landing impact problems of lunar landing.

Completion time is estimated to be 1 to $1\frac{1}{2}$ years.

Particle Accelerator for Simulation of Micrometeoroid Impact

This facility consists of an electrostatic particle accelerator to achieve microparticle velocities up to about 80,000 feet per second. Existing particle accelerators using the light gas gun principle have been brought to the point that speeds of 30,000 feet per second have been achieved and show some promise for going even higher to perhaps 40,000 feet per second. To go appreciable higher than that requires a different principle of acceleration (natural meteoroids have speeds between 30,000 and 250,000 feet per second). Construction time is estimated to be slightly more than 1 year.

Stabilization and Control Equipment Laboratory

This facility includes inertial simulators for instrument mounting; electronic simulation facilities for closed-loop integrated systems studies; medium-high-vacuum equipment for long-time-operation, low-torque control system investigation; long-throw optical facilities for use with simulators; equatorial and time-drive mounts for use with sun, star, and planet seekers; magnetic field control to simulate the fields encountered in space; and a special building to accomodate the long-throw optical arm and other special requirements. This facility is needed at the Langley Research Center for the proper support of Atlas-Agena reentry flights and for augmented direct support of guidance and control problems of Apollo.

Procurement and use of many elements of the equipment would begin immediately. Estimated completion of facility, including the building, is 1 year.

Space Propulsion Test Facility

This facility consists of a vacuum tank of 300,000 cubic feet volume provided with cooled walls, movable solar radiation sources, a three-axis table, and analog control equipment. It is needed at the Lewis Research Center to study attitude-control rocket motors, solar electric power generation, propellant tank problems including insulation, and propulsion system interactions.

Total construction is estimated to be 3 years.

Turbo-Pump Facility

This project involves expansion of existing Lewis Plum Brook propellant facilities for handling and storage of cryogenics and added instrumentation. It is needed to study the design problems of the required large turbo pumps for hydrogen engines for Nova vehicles.

Estimated completion time is 2 years.

Equipment to Study Propulsion System and Component Interaction

This proposal is for analogue computer equipment capable of dealing with point mass and real-body motions under the influence of propulsive forces, and inertia and gravity torques, with reference to the dynamics of various elements of the space vehicle, i.e., lunar landing and take-off configurations and the launch vehicle system.

Environmental Chamber for Study of Energy Converters

This facility consists of a 20-foot-diameter, 30-foot-long vacuum chamber with associated equipment and instrumentation for studying the performance of energy converters such as solar collectors and cells and fuel cells in the simulated space environment.

Estimated construction time is 1 year.

Propellant Expulsion Facility

This proposal is for extension of existing Lewis facilities for the study of techniques for pressurization and expulsion of propellants from full-scale, multiple, interconnected propellant tanks under static and dynamic conditions.

Estimated completion time is 1 year.

Meteoroid Sensor and Instrument Facility

This facility consists of a 15-foot-diameter, 30-foot-long vacuum chamber for the study and development of meteoroid sensors and packages for free-flight experiments.

Completion time 1 year or less.

Radio-Wave Attenuation Facility

This facility consists of a large volume chamber with altitude capability (not high vacuum) for the creation of realistic rocket plumes. It is needed for the study of rocket exhaust attenuation of EM signals as in the employment of radio altimeter to measure height above lunar surface.

Completion time is 1 year.

Equipment for Study of Electromagnetic Shielding Against Charged Particle Radiation

This proposal is for cryogenic equipment to produce temperatures down to one-degree Kelvin for the creation of strong fields with superconducting electromagnets. This equipment is needed to study the potentialities of unconventional shielding techniques against penetrating space radiation.

Acquisition of equipment one year or less.

Dust Tank

This facility consists of a 10-foot-diameter, 20-foot-long hard vacuum chamber with provision for the electrostatic charging of dust particles, simulating the potential lunar environment experienced by a landing vehicle. The facility is needed for study of phenomena encountered with neutral and charged particles and interactions with spacecraft materials and components.

Completion time 1 year.

APPENDIX

Nova Noise Problem

Summary and Recommendations

1. A great deal is known in general about noise and about the scaling of jets and rockets, which permits us to extrapolate with some confidence to large, "Nova class" vehicles.

2. On the basis of this scaling we can say with some assurance that if the same propellants are used the maximum sound pressure levels will be no greater than for present vehicles; they will extend over greater areas. For example, we can expect a 20,000,000# Nova to have the same noise levels as Atlas at a distance 8 times as great.

3. The main difference, besides the greater distance, is that the frequencies of a 20M# Nova will be reduced by a factor of 8 with regard to Atlas. Thus a great deal of the noise energy will appear below 20 cycles, which is the lower cut off frequency of the ear.

4. The greatest area of uncertainty is the response of people and buildings to the subaudible frequencies of relatively high intensities. It is believed that damage to light buildings may be the critical items.

Conclusions, based on present knowledge:

1. There is no significant difference in noise intensities of solid or liquid rockets of the same thrust and specific impulse.

2. It is expected that the noise from a 20M# Nova will produce some plaster and shingle loosening on frame building at 1 mile and up to 5 miles, depending somewhat on construction, condition of building, and weather; and to be safe from both human factor and building damage considerations a distance of 10 miles between community and launch site is desirable.

3. Blast damage of a completely efficient explosion of a 20M# Nova (equivalent approximately to the detonation of 1 kt of TNT) would produce nearly complete destruction of frame housing to $\frac{1}{2}$ mile, and less damage up to a distance of 5 miles (window breakage, etc.).

Recommendations:

1. It is recommended that a short but comprehensive study be made by contract (preferably Bolt, Baranek, and Newman) of the special problems around Canaveral with regard to Nova launch site. (It would probably be advantageous to have the contractor work closely with Langley and Marshall in this study).

2. It is further recommended that research on response of buildings and people to very low frequencies be started, both at the research centers and contract.

3. It is recommended that very careful consideration be given to orientation of firing and test stand so as to minimize the community noise problem. This can be done by pointing the maximum sound radiation away from the most populated areas, and using terrain wall and water as attenuating factors.

Noise Problems of Nova Type Boosters

Arthur A. Regier
Langley Research Center

This brief discussion will present some sound pressure and frequency estimates for large boosters, and some of the structural and human factors problems to be considered, particularly with regard to launch site requirements.

The decibel scale, equivalent pressures and some phenomena associated with the various noise levels are shown in figure 1. One should be cautioned that particular phenomena are a function of sound duration and frequency as well as pressure, and hence one cannot draw general conclusions.

An example of this is illustrated in figure 2 which shows an equal perceived noise contour as function of pressure and frequency. This curve shows that at low frequencies a sound pressure level of 120 decibels sounds no louder than a sound of 90 decibels at the high frequencies. It will be shown that for the larger boosters the dominant frequency of the noise is in sub audible frequency range (below the frequency at which an ear can detect noise) and hence noise as it is commonly experienced with regard to ear is not a problem; what problems the low frequency noise will present with regard to humans reaction and buildings respectively has not been adequately explored.

Consider some characteristics of rocket noise. Figure 3 shows measured sound pressure contours of the Saturn during static firing. The intensity is a maximum--approximately 30° on either side of the jet--and is a minimum in the direction opposite the jet efflux. In considering any test stand or launch site it is important to point the jet exhaust toward an area of minimum populations, and preferably over water. Water, both as a jet deflector coolant, and exhausting over a body of water are known to reduce the static firing noise greatly.

During the vertical ascent of the vehicle the noise at a given field location will increase as the vehicle rises, because the noise increases as the high pressure lobe points toward the observer. This phenomenon is illustrated in some measurements made in the surrounding area, during the launch of Big Joe by an Atlas. It may be noted (figure 4) that as the Atlas rises, the noise peaks first at the near stations and at a later time at the stations further away. The maximum

DECIBELS	PRESSURE, PSI	PHENOMENA
180	3.0	RAPID FAILURE
160	0.3	AIRCRAFT STRUCTURE FATIGUE
140	0.03	LOOSENS PLASTER BOARD AND SHINGLES
120	0.003	PAIN IN EARS
100	0.0003	SPEECH INTERFERENCE

L-36F413 NASA - Langley Field, Va.

Figure 1

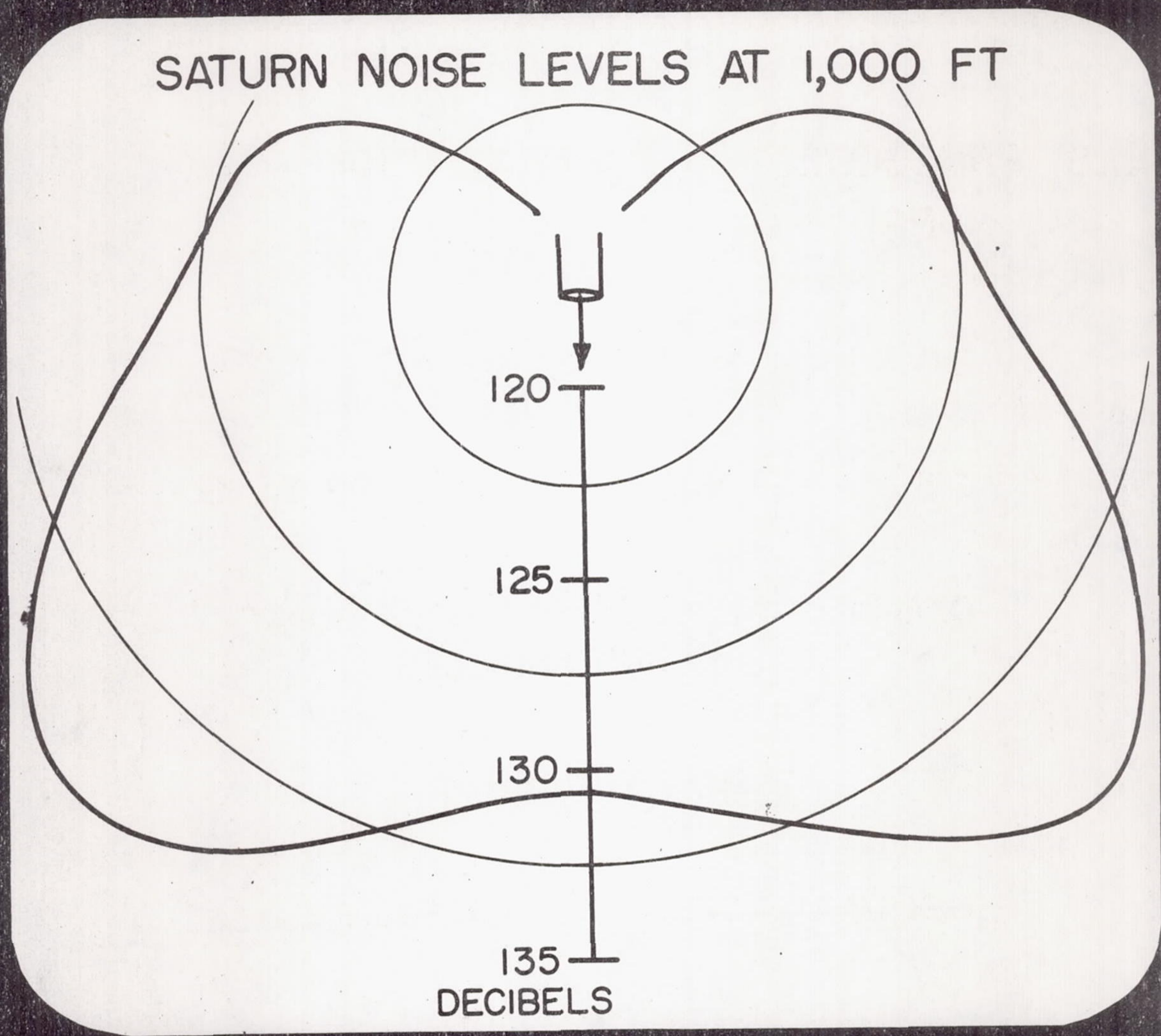


Figure 3

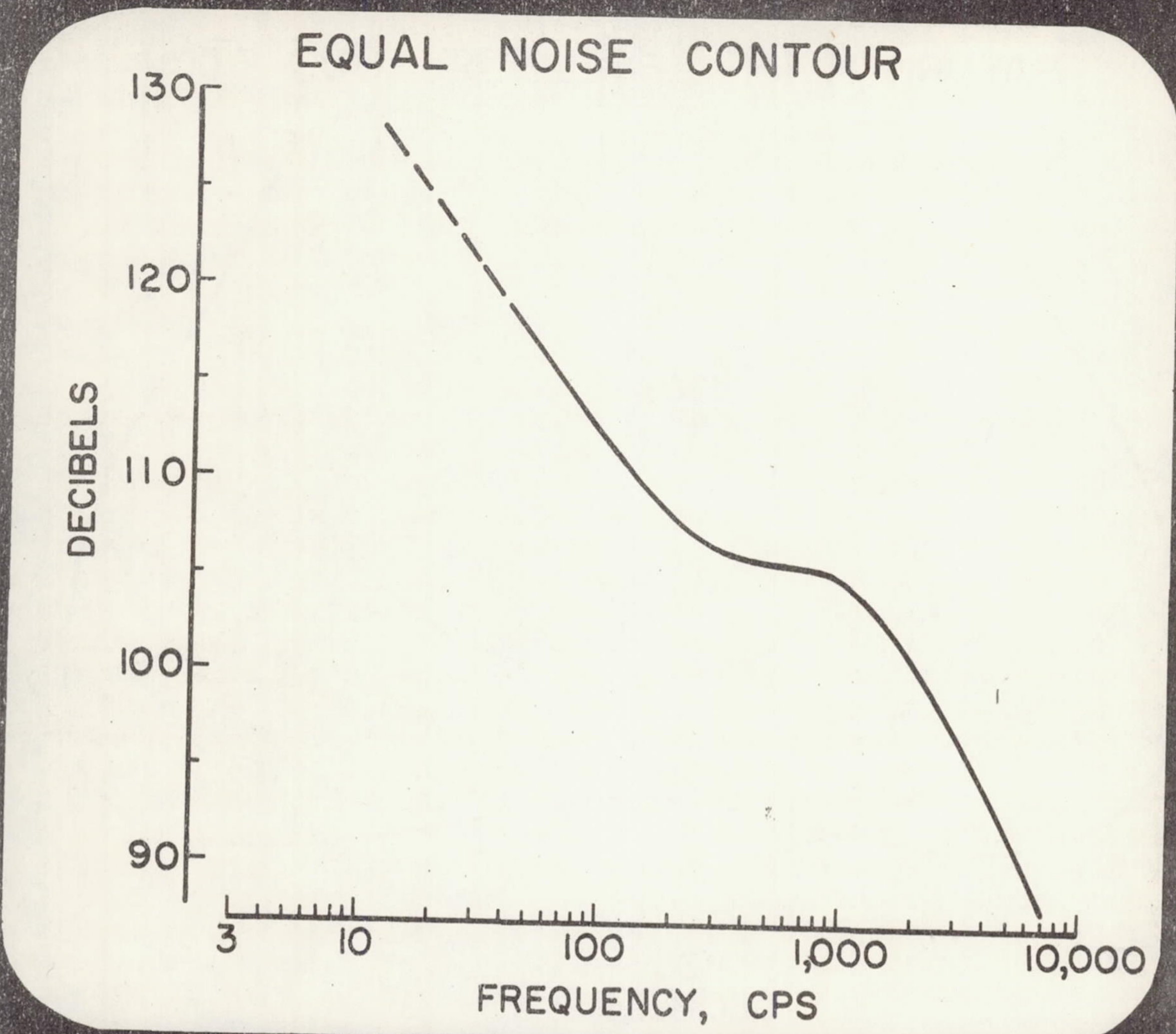
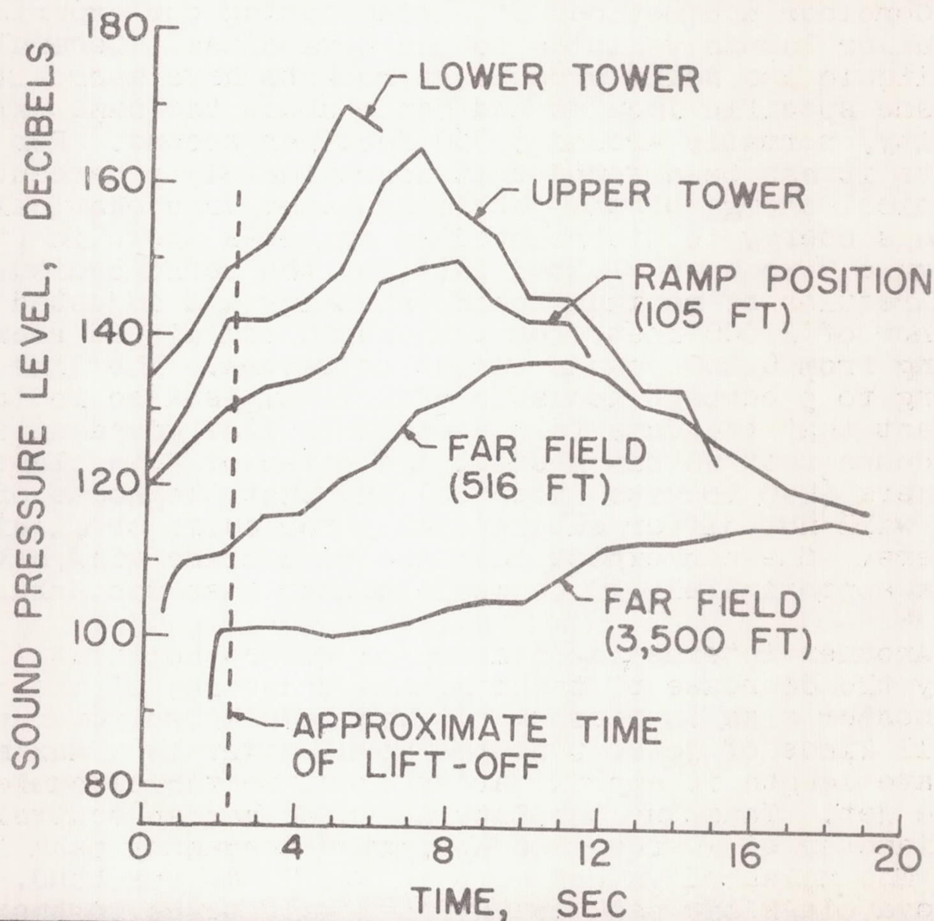

EQUAL NOISE CONTOUR
130
120
110
100
90
DECIBELS
3
10
100
1,000
10,000
FREQUENCY, CPS

Figure 2

ATLAS NOISE DURING LAUNCH

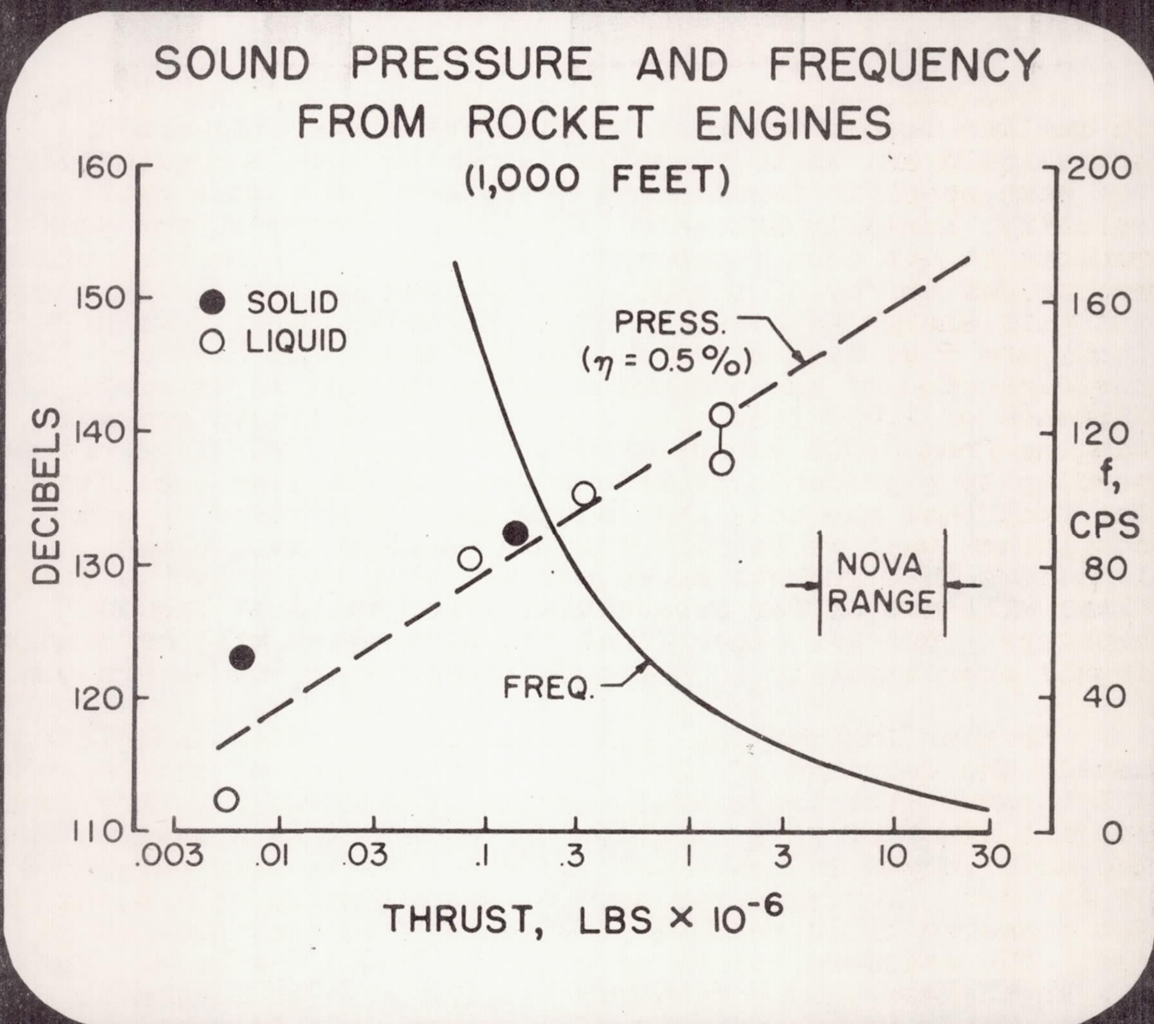


value of the peak pressures, of course, decrease with distance. For larger launch vehicles one would expect the same phenomenon to occur, except that the same noise levels would occur at greater distances away, and the noise would have lower frequencies. There is no practical way of shielding the community from the lift-off noise, except by increasing the distance. Fortunately this noise is of short duration and occurs infrequently. Hence the community tolerance to this noise is likely to be high, unless it causes physical damage.

Consider now methods of extrapolating our experience on smaller launch vehicles to the Nova class. Generally both liquid and solid propellant rockets have approximately the same specific impulse and hence about the same exit velocity, normally around 8,000 feet per second. For such rockets it has been found that approximately $\frac{1}{2}$ percent of the mechanical energy of the jet is radiated as acoustical energy, and this energy is distributed in space as shown in figure 3. In figure 5 we have plotted data for the sound pressure for the direction of maximum sound intensity and adjusted to a distance of 1,000 feet, for both solid and liquid rockets ranging from 6,000 pounds thrust to Saturn. The line corresponding to $\frac{1}{2}$ percent acoustic efficiency is also indicated. The fact that the data fall along this line gives us some confidence that we can predict the noise of Nova class launchers (H-O rockets excepted) and that the noise of this class will not differ substantially for solid or liquid boosters. One can expect that the Nova class will have noise levels approximately 10 decibels higher than the Saturn vehicle.

Another interesting feature of rocket noise is illustrated, namely the decrease of the dominant frequency of the noise as the booster size increases. It has been known for many years, for all kinds of jets, that the sound power is a maximum when the wave length is approximately equal to the circumference of the jet. Thus for the Saturn, which has an equivalent jet diameter of 10 feet the extimated frequency peak is 36 cps. The measured values were in the 30-40 cps band. For the Nova class the peak energy is likely to be in the 10 cps range, which is below the audible range. It is very likely that as far as the ear is concerned the Nova will sound no louder than the Atlas or Saturn, at a given distance from launch. There will, however, be a great deal of energy in the low frequencies.

Another question that is raised is with regard to structural integrity of the vehicle due to noise and the noise exposure of the astronaut. One can make estimates of this on the basis of non dimensionalizing the distance as is shown in figure 6. If the rockets have about the same exit velocity, one should expect that the same total sound


SOUND PRESSURE AND FREQUENCY
FROM ROCKET ENGINES
(1,000 FEET)
SOLID
LIQUID
PRESS.
(η = 0.5 %)
FREQ.
NOVA
RANGE
DECIBELS
f,
CPS
THRUST, LBS × 10^{-6}
160
150
140
130
120
110
200
160
120
80
40
0
.003
.01
.03
.1
.3
1
3
10
30

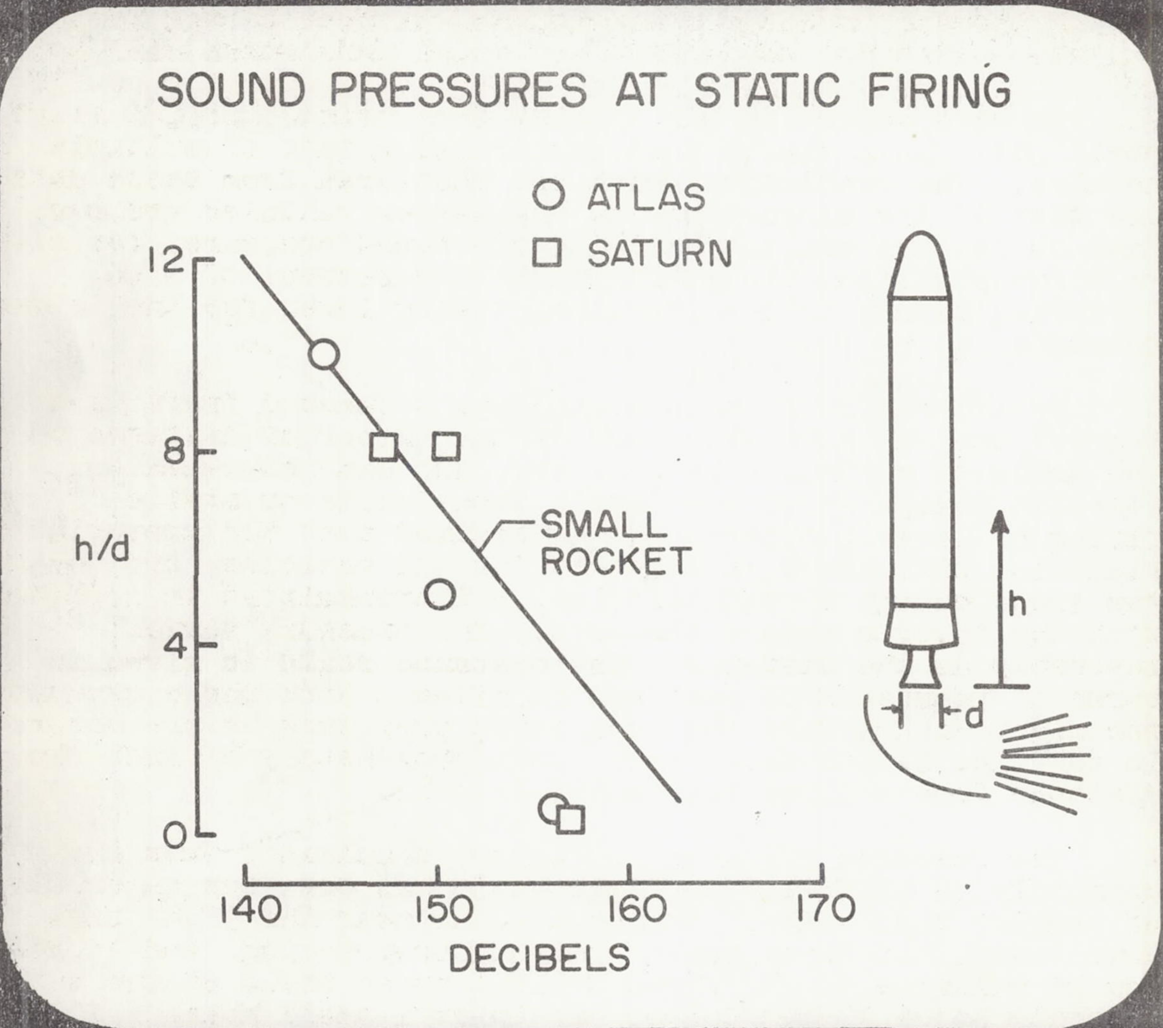
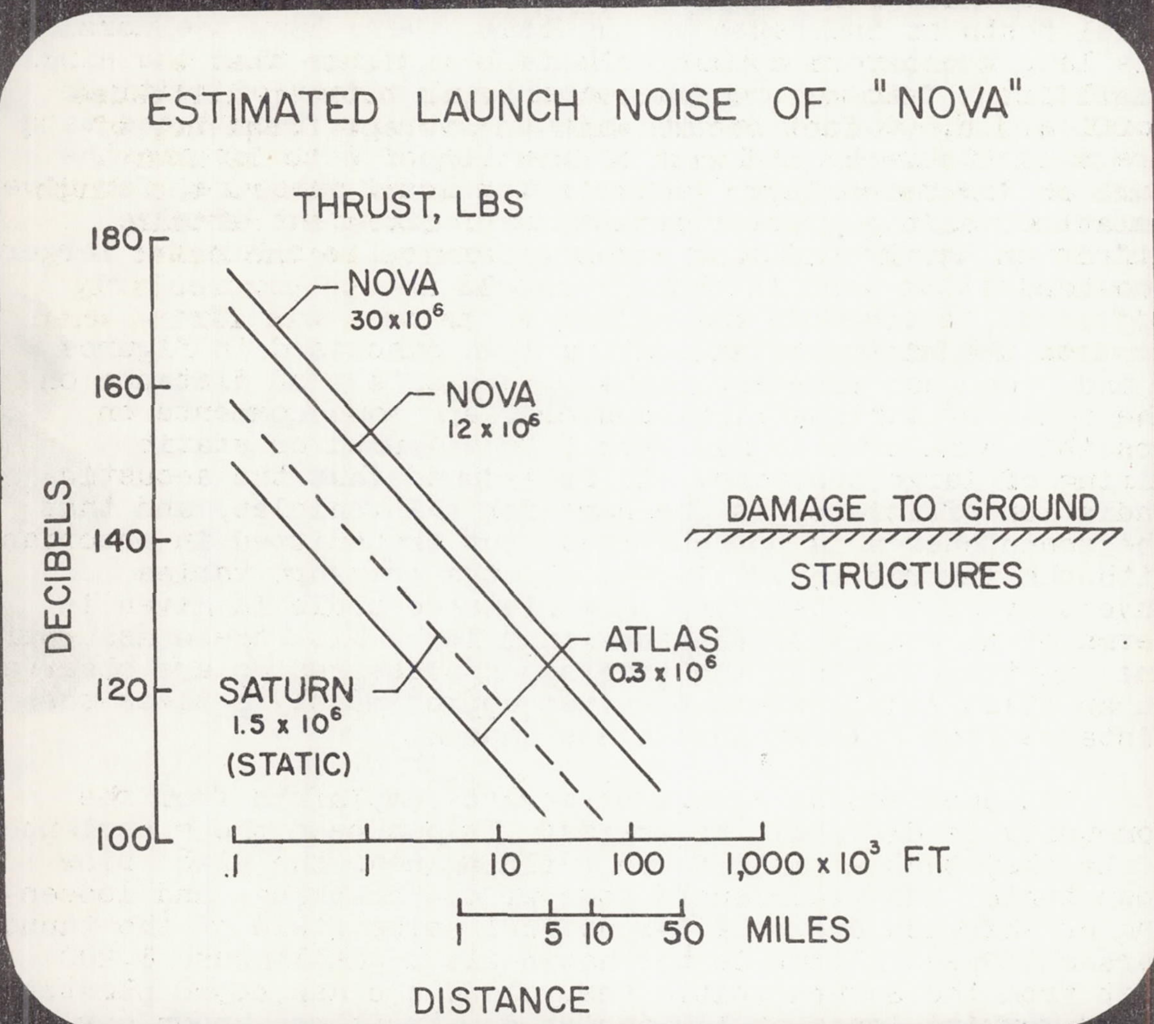

SOUND PRESSURES AT STATIC FIRING
ATLAS
SATURN
12
8
4
0
h/d
SMALL
ROCKET
140
150
160
170
DECIBELS
h
d

Figure 6

pressure would result at a given number of jet diameters from the source. This is illustrated in figure 6, in which the sound pressures along the side of Atlas and Saturn are plotted in terms of h/d, where h is distance from nozzle exit along vehicle and d is the diameter of a single nozzle having the same area as the total nozzle area of the respective vehicle. Also for comparison are shown some small Jato bottle model tests as indicated by the line. Very near the nozzle the larger boosters appear to have less noise than the single small jet. This may be some beneficial effect of multiple nozzles. The conclusion which one must draw from these data are that if the proportions of the larger vehicles are the same as for the smaller vehicles the sound pressure, for given relative position, are likely to be independent of size, differing mainly in the frequency, being lower for the larger boosters.

On the basis of the scaling laws discussed in figures 5 and 6 one can make estimates of the effect of distance on the noise of various size boosters, and some comments on possible damage which may result from launch or static firing of large boosters. It is assumed that the acoustic radiation efficiency is the same for all vehicles, and that the sound energy is not absorbed, but transmitted in accordance with the inverse square law--i.e., the pressure varies inversely as the distance. The distance scale is given in terms of thousands of feet and in miles. With these assumptions one might expect that the same sound pressures as are observed in an Atlas launch would occur at approximately 8 times the distance from a large Nova class launch.

The question of damage or severe complaints from the community is difficult to assess. It has been the experience of Langley that a small frame building near the 9'x6' blow down tunnel has experienced some window cracking, and loosening of shingles due to a 140 decibel noise field of the tunnel. Marshall Space Flight Center has built a small house 1,200 feet from the Saturn static test stand and has noted plaster board working loose at 140 decibels. It is not known how residential type construction would withstand the same noise levels at lower frequencies associated with the large boosters. There is some reason to believe that the lower frequencies may do more damage, because the building frequencies are likely to be in this range. It would therefore appear undesirable to expose community to 140 db, which would occur at approximately 1 mile from a Nova launch site. It would appear that a distance of 10 miles should be safe for launching; however, this distance might cause complaint from frequent test firings.


ESTIMATED LAUNCH NOISE OF "NOVA"
THRUST, LBS
NOVA
30 x 10^6
NOVA
12 x 10^6
ATLAS
0.3 x 10^6
SATURN
1.5 x 10^6
(STATIC)
DAMAGE TO GROUND
STRUCTURES
DECIBELS
180
160
140
120
100
.1
1
10
100
1,000 x 10^3 FT
1
5
10
50
MILES
DISTANCE

Additional Notes on Aspects of the
Noise Problem at AMR

1. There have been no serious complaints about noise or noise and blast damage to date from the operations at Cape Canaveral, including the experience of two explosions (an Atlas and a Jupiter), one of which did $1 million damage to the launch pad.

2. Weather records at the Cape indicate that a significant temperature inversion layer between altitudes 5,000 and 6,000 feet occurs with an average frequency of about once a week, and with a duration of 6 to 12 hours. Such an inversion layer refracts the sound toward the earth and results in a greater intensity of sound at certain points on the ground than would otherwise be the case. The indication here is that it should not be particularly difficult to schedule operations so as to avoid firing when adverse conditions exist.

CONFIDENTIAL

PART II

SECTION G

PROGRAM FUNDING
FOR
EARLY MANNED LUNAR LANDING

Dr. Albert J. Kelley
Office of Programs
NASA

June 16, 1961

CONFIDENTIAL

PROGRAM FUNDING

A study of funding requirements was initiated at the outset by the Ad Hoc Committee, together with investigations of technical parameters and schedule planning. A range of budgetary estimates for program items was obtained which was adjusted concurrently with adjustments in SMS event planning. Three major consolidations and reviews of the entire budget package was made which resulted in narrowing down the span of budgetary estimates to "hard numbers" for the first and second years' funding requirements. Budgetary figures for following years were built up in a similar manner and are considered to be as good estimates as can be made for the period of projection.

The budget package has been built from the bottom up and is a "requirements" budget to accomplish the manned lunar landing task. Individual items were analyzed to determine their contribution to the program, their relationships to other program items, funding rate and total funding required. Arbitrary budgetary ceilings were not imposed on items or categories of items. Pages G-2 through G-7 show a breakdown of fiscal requirements by major funding items and funding year. Principal categories are:

Spacecraft
Launch Vehicles and Instrumentation
Lunar and Space Sciences
Life Sciences
Range and Tracking Instrumentation
Advanced Technology

Page G-8 shows the total funding by category for the manned lunar landing task and is a composite of pages preceding. This total funding chart as shown is identical to the category breakdown chart presented in Part I - Summary Report. Thus it includes Saturn C-3 and Nova launch vehicles with liquid propellant booster stages.

For comparison of the funding effects of liquid and solid propellant booster stages, the entire category of <u>Launch Vehicles and Operations</u> is shown on page G-3a wherein solid booster stages replace liquid booster stages. The principal differences between items in pages G-3 and G-3a are (1) the substitution of the solid engine and stages vice the F-1 engines and stages, and (2) substitution of solid vice liquid launch pads. Other itemized costs have been adjusted as applicable. Because of the difference in technological development and state-of-the-art between large liquid and large solid booster engines, the funding estimates shown on page G-3a have a lower confidence level than those shown on page G-3.

Funding estimates are presented on the basis of funding years from program start. The whole program can be adjusted to fit initial budgetary constraints with, of course, the end date moving accordingly. Part I - Summary Report contains a discussion showing that a project initiation date of August 15, 1961 gives excellent funding correlation between the Ad Hoc Committee results and currently planned NASA budgets for FY 62 and FY 63.

SPACECRAFT

	Funding Year						
	1st	2nd	3rd	4th	5th	6th	Totals
Development - R&D	197	532	1039	1175	569	255	3767
18 Orbit Mission	32	53	15	----	---	---	
14 Day Animal	30	30	2	----	---	---	
Model Reentry Tests	31	34	5	----	---	---	
Biomedical Satellites	30	71	18	----	---	---	
Conceptual Tests	15	22	35	74	55	20	
Apollo Spacecraft	35	190	414	406	216	90	
Lunar Landing Stage	10	56	210	315	120	60	
Lunar Takeoff Stage	14	76	340	380	178	85	
Facilities - C of F	28	54	6	1	1	---	90
Manned Space Flight Center	23	37	5	----	---	---	
Spacecraft Operations Facility	2	8	1	1	1	---	
Spacecraft Propulsion Development Facility	3	9	---	----	---	---	
Totals	225	586	1045	1176	570	255	3857

CONFIDENTIAL

LAUNCH VEHICLES AND OPERATIONS
(Assumes Liquid Booster Stages for Saturn C-3 and Nova II)

	Funding Year						
	1st	2nd	3rd	4th	5th	6th	Totals
Development - R&D	454	865	1350	1187	644	278	4778
Saturn C-1	180	61	17	5	---	---	
Saturn C-3	87	276	517	347	156	81	
Nova II	70	369	679	750	428	162	
Propulsion	117	159	137	85	60	35	
F-1 Engine							
J-2 Engine							
Y-1 Engine							
Facilities - C of F	206	414	247	37	---	---	904
Saturn C-1 Test and Launch	51	24	5	1	---	---	
Saturn C-3 Mfg. and Test	28	61	3	3	---	---	
Nova II Mfg. and Test	34	165	7	6	---	---	
Propulsion Development and Test	24	46	7	----	---	---	
Saturn C-3 Launch Complex	29	61	130	----	---	---	
Nova II Launch Complex	40	57	95	27	---	---	
Totals	660	1279	1597	1224	644	278	5682

CONFIDENTIAL

CONFIDENTIAL

LAUNCH VEHICLES AND OPERATIONS
(Assumes Solid Booster Stages for Saturn C-3 and Nova IV)

	Funding Year						
	1st	2nd	3rd	4th	5th	6th	Totals
Development - R&D	351	601	884	1087	835	378	4136
Saturn C-1	180	61	17	5	---	---	
Saturn C-3	46	126	295	286	173	55	
Nova IV	38	265	447	746	632	308	
Propulsion	87	149	125	50	30	15	
Solid Engine							
J-2 Engine							
Y-1 Engine							
Facilities - C of F	188	311	310	53	---	---	862
Saturn C-1 Test and Launch	51	24	5	1	---	---	
Saturn C-3 Mfg. and Test	22	43	2	3	---	---	
Nova IV Mfg. and Test	27	54	7	---	---	---	
Propulsion Dev. and Test	19	32	7	---	---	---	
Saturn C-3 Launch Complex	29	57	121	---	---	---	
Nova IV Launch Complex	40	101	168	49	---	---	
Totals	539	912	1194	1140	835	378	4998

CONFIDENTIAL

CONFIDENTIAL

LUNAR AND SPACE SCIENCES

	Funding Year						
	1st	2nd	3rd	4th	5th	6th	Totals
Development - R&D	133	232	315	311	295	269	1555
Ranger	64	59	18	---	---	---	
Surveyor A	53	55	111	72	96	96	
Surveyor B	2	18	51	63	12	---	
Prospector	--	38	62	98	109	95	
Scientific Satellites and Sounding Rockets	14	62	73	78	78	78	
Facilities - C of F	7	4	2	1	---	---	14
Vacuum Chamber - 30x40							
Vacuum Chambers - 10x20							
High Frequency Shaker							
Low Frequency Shaker							
Acoustical Chambers							
Range Checkout Facility							
Radiation Test Facility							
Totals	140	236	317	312	295	269	1569

CONFIDENTIAL

LIFE SCIENCES

	Funding Year						
	1st	2nd	3rd	4th	5th	6th	Totals
Development-R&D	26	33	45	45	33	11	193
Aerospace Medicine	8	12	20	20	15	5	
Space Biology	2	3	5	5	3	1	
Flight Programs	16	18	20	20	15	5	
Facilities-C of F	4	16	2	1	--	--	23
Vacuum Chamber - 60' Dia.							
Life Science Research Facility							
Space Flight Training Center							
Radiation Research Facility							
Totals	30	49	47	46	33	11	216

RANGE AND TRACKING INSTRUMENTATION

	Funding Year						
	1st	2nd	3rd	4th	5th	6th	Totals
Development - R&D	19	53	30	10	--	--	112
Augment Existing Stations Apollo Track and Data System Des. Air Drop Instr. Apollo Orbit Instr. Apollo Lunar Instr. Lunar Transponder Reentry and Recovery Instr. Range Safety and Abort GSE Launch Site Instr. Development							
Facilities - C of F	12	45	59	30	--	--	146
Reentry Model Recovery Instr. New Tracking Station Equip Two TM Ships Equip Two Track Ships Add. 85' DSIF Antennas Central Control Center Manned Reentry and Recovery Instr. Launch Site Instr.							
Totals	31	98	89	40	--	--	258

ADVANCED TECHNOLOGY

	Funding Year						
	1st	2nd	3rd	4th	5th	6th	Totals
Development - R&D	17	40	16	--	--	--	73
Reentry Studies and Flight Tests							
Nav., Guidance and Control							
Radiation and Shielding							
Lunar Earth Landing							
Artificial Gravity							
Micrometeroid Damage							
Wind Shear							
Noise Studies							
Launch Vehicle Design Criteria							
Facilities - C of F	15	13	--	--	--	--	28
Low Freq. Noise Facility							
Space Rad. Effects Lab.							
Microparticle Accelerator							
Environmental Test Facilities							
Manned Lunar Landing Simulator							
Sensor Lab.							
Arc Tunnel Augmentation							
Space Propulsion Test Facility							
Totals	32	53	16	--	--	--	101

CONFIDENTIAL

CONFIDENTIAL

CONFIDENTIAL

TOTAL FUNDING
SPECIAL STUDY TASK
R&D AND CofF

Funding Year

	1st	2nd	3rd	4th	5th	6th	Totals
Spacecraft	225	586	1045	1176	570	255	3857
Launch Vehicles and Operations	660	1279	1597	1224	644	278	5682
Lunar and Space Sciences	140	236	317	312	295	269	1569
Life Sciences	30	49	47	46	33	11	216
Range and Tracking Instrumentation	31	98	89	40	--	--	258
Advanced Technology	32	53	16	--	--	--	101
Totals	1118	2301	3111	2798	1542	813	11,683

CONFIDENTIAL

CONFIDENTIAL

Restriction/Classification Cancelled

CONFIDENTIAL